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Alert 2002 Ground Truth Missions for Arctic Shoreline Delineation and Feature Extraction

Karim E. Mattar, Lloyd Gallop and Janice Lang

Defence R&D Canada - Ottawa
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Alert 2002 ground truth missions for Arctic shoreline delineation and feature extraction

Karim E. Mattar
Defence R&D Canada - Ottawa

Lloyd Gallop
Defence R&D Canada - Ottawa

Janice Lang
Defence R&D Canada - Ottawa

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Abstract

This technical memo is part of a study to develop and test tools and techniques for improved accuracy, reliability and automation of shoreline delineation and feature extraction, with particular emphasis on the arctic environment. This memo details the RADARSAT imagery and extensive ground truth collected during the spring and summer of 2002 in CFS Alert, Nunavut. The ground truth includes deployment of four radar corner reflectors, measurement of several shorelines and a large variety of other tracks, measurement of a large variety of permanent scatterers and targets of opportunity, extensive photographic record, comparison of the measured and modeled tide at CFS Alert, and plots of the weather during the time period concerned.

Résumé

Le présent document technique fait partie d'une étude visant à élaborer et à mettre à l'essai des outils et des techniques destinés à améliorer la précision, la fiabilité et l'automatisation de la délimitation et de l'extraction de caractéristiques du rivage, en accordant une importance particulière à l'environnement arctique. Il décrit les données d'imagerie RADARSAT et les données de terrain détaillées recueillies au printemps et à l'été 2002 à la SFC Alert, au Nunavut. La vérification au sol comprend la mise en place de quatre réflecteurs radar en coin, la mesure de plusieurs rivages et d'une grande variété d'autres trajectoires, la mesure d'une grande variété d'objectifs inopinés et de diffuseurs permanents, l'acquisition d'un enregistrement photographique étendu, la comparaison des marées mesurées et modélisées à la SFC Alert, et l'acquisition de graphiques météorologiques pour la période considérée.

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Executive summary

The current world vector shoreline database includes unacceptably large errors. As a means of improving this database, the Vector Shoreline Project was initiated between the National Imagery and Mapping Agency (NIMA) and the Defence Research Establishment Ottawa (DREO) in 1998. The primary focus of this study is on the development of tools and techniques to improve shoreline detection accuracy. In addition, this study also seeks to improve the automation and reliability of map finishing and feature extraction. The tools and techniques developed will be based on interferometric coherence and phase information, both of which are particularly suitable for arctic environments.

This memo forms part of the Vector Shoreline Project. Its purpose is to detail the collection of the RADARSAT data and the ground truth data acquired during the spring and summer of 2002 at Canadian Forces Base (CFB) Alert, Nunavut. It is hoped that this database will serve, and even initiate other studies.

Sixteen fine beam RADARSAT images were collected over the periods extending from 23 March to 14 May, and from 27 July and 1 September, 2002. Four additional images will be added to this set following their collection later this fall and winter. To date, 7 interferometric pairs have been successfully processed to the interferogram stage. Further processing of this data will be detailed in another report.

The ground truth was collected over a period of approximately 27 days in the spring, and 16 days in the summer. This consisted of deployment of four radar corner reflectors, measurement of several shorelines and a large variety of other tracks, measurement of a large variety of permanent scatterers and targets of opportunity and the acquisition of extensive photographic record. Other ground truth activities include the measurement of the tide at Alert, its comparison to the modeled tide, and the acquisition of weather plots during the time period concerned.

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Sommaire

La base mondiale actuelle de données vectorielles sur le rivage comprend des erreurs trop grandes pour être acceptées. Dans le but d'améliorer cette base de données, on a mis sur pied le projet sur les données vectorielles de rivage entre l'agence nationale américaine de cartographie et d'imagerie (NIMA) et le Centre de recherches pour la défense Ottawa (CRDO) en 1998. Cette étude vise principalement à élaborer des outils et des techniques destinées à améliorer la précision de la détection des données de rivage. Elle vise également à améliorer l'automatisation et la fiabilité de la finition des cartes et de l'extraction de caractéristiques. Les outils et les techniques élaborés seront basés sur la cohérence interférométrique et sur l'information de phase, deux éléments qui conviennent particulièrement bien pour l'environnement arctique.

Le présent document fait partie du projet sur les données vectorielles de rivage. Il vise à décrire en détail la collecte des données RADARSAT et des données de terrain effectuée au printemps et à l'été 2002 à la Base des Forces canadiennes (BFC) Alert, au Nunavut. On espère que cette base de données sera utilisée dans d'autres études et qu'elle servira même à en lancer de nouvelles.

Seize images RADARSAT ont été acquises en mode faisceau fin pendant les périodes allant du 23 mars au 14 mai et du 27 juillet au 1er septembre 2002. Quatre autres images seront ajoutées à cette série après leur collecte plus tard au cours de l'automne et de l'hiver. À ce jour, 7 paires interférométriques ont été traitées avec succès au stade de l'interférogramme. Le traitement plus poussé de ces données sera décrit dans un autre rapport.

Les données de terrain ont été recueillies sur une période d'approximativement 27 jours au printemps et 16 jours à l'été. L'opération a nécessité la mise en place de quatre réflecteurs radar en coin, la mesure de plusieurs rivages et d'une grande variété d'autres trajectoires, la mesure d'une grande variété d'objectifs inopinés et de diffuseurs permanents et l'acquisition d'un enregistrement photographique étendu. Les activités de vérification au sol comprenaient également la mesure de la marée à Alert et sa comparaison avec la marée modélisée, et l'acquisition de graphiques météorologiques pendant la période considérée.

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Acknowledgements

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Introduction

In 1998 a two-year project, entitled the Vector Shoreline Project, was initiated between the Defence Research Establishment Ottawa (DREO) and the National Imagery and Mapping Agency (NIMA), USA. The aim of the project was to investigate techniques and develop tools for improved shoreline extraction from imagery. A global shoreline database had previously been compiled by NIMA, based on airborne photogrammetry techniques and existing maps. The database provided an estimate of the global shoreline with 500 m error limits for 90% of all shorelines. The project was initiated when it became obvious that operational requirements necessitated shoreline delineation with greater accuracy than was available in the currently database.

The project resulted in the publication of two reports from Defence R & D Canada – Ottawa (DRDC Ottawa) (formerly DREO). The first [1] focused on polarimetric Synthetic Aperture Radar (SAR) techniques for shoreline delineation, predominantly in temperate environments. The second [2] investigated the use of interferometric SAR (InSAR) coherence for shoreline delineation in temperate and arctic environments. It concluded that in temperate environments coherence is not a reliable technique for shoreline extraction. However, coherence appeared to be a very useful technique for arctic shoreline delineation.

Both studies clearly indicated that the very large variety of shorelines existing globally would require a variety of techniques and tools to delineate to the required accuracy.

In general, the final stage of creating a map to digital terrain elevation data (DTED) standards remains very manually intensive, and therefore expensive, process. To improve the automation and reliability of global shoreline delineation and feature extraction requires a variety of tools and techniques.

This study was initiated when we were presented with an opportunity to collect valuable ground truth in Alert, Nunavut, at minimal expense to this project. The overall motivation is the lack of accurate maps of the Canadian Arctic. The Arctic is a unique environment, and as such presents unique challenges to shoreline delineation and feature extraction.

The purpose of this study is to develop, refine, and test tools and techniques for improved map finishing accuracy, reliability, and automation, with particular emphasis on shoreline delineation and feature extraction. Currently these tools and techniques are based on interferometric coherence and phase information. It is anticipated that with the launch of RADARSAT-2, this study will be expanded to take advantage of the improved resolution, full polarimetric SAR, and polarimetric interferometry of the new satellite.

The purpose of this technical memo is to document the extensive ground truth data that was collected during the spring and summer 2002 mission in and near Alert. We expect that this data will be applicable to many future studies. This report is divided into several sections. After outlining the experimental objectives and describing the experimental site, we will detail the RADARSAT data acquired and the ground truth collected. To ensure a thorough understanding of the scope of the ground truth data collected, four appendices are attached.

The first two lists measured GPS tracks and waypoints. The third and fourth lists the photographs taken in and around Alert during the spring and summer 2002 mission.

Experiments

Arctic environments are particularly challenging to map accurately and efficiently. In optical frequencies the clouds, snow, and ice obscure many features. In radar images layers of snow and ice can also obscure the ground and shoreline. In radar interferometry, ionospheric and tropospheric effects can distort the interferometric phase, thereby adversely affecting mapping and feature extraction and recognition. Technologies and tools that can improve mapping accuracy in such environments will undoubtedly prove particularly useful, and even more so if these tools are automated.

Two recent DRDC Ottawa Technical Reports discussed the challenges of shoreline delineation [1, 2]. The later examined shoreline delineation using the interferometric coherence in a variety of environments. It concluded that in tropical environments, shoreline delineation using coherence is feasible, but not reliable. Changes in the environment due to rain and vegetation growth, as well as volume decorrelation, all serve to obscure the shoreline. Conversely, coherence was successfully used for coastline and lake shoreline delineation in arctic environments. Subtle changes in the level of the sea ice from tidal variation served to delineate the shoreline in the coherence map. Changes in the volume scattering of the frozen lakes compared with its immediate environment outlined the frozen lakes in the coherence image. This particular study expands on and extends the report for shoreline delineation and feature/target detection and recognition.

Shoreline & Coastline Delineation

The first aim of this study is to maximize, and subsequently measure the shoreline delineation accuracy using interferometric coherence. For mapping applications to adhere to DTED standards, accurate delineation of the coastline, as well as shorelines of lakes, rivers, and drainage basins is required. In addition, shoreline and drainage line delineation is currently the most manually intensive portion of the mapping process. Any improvements in automation of these will be significant.

Towards this aim extensive ground truth, detailed in this memo, has been collected. This includes ground control points (GCPs) to help with geocoding, global positioning system (GPS) measurements of shorelines to provide an independent measurement, collection of tidal information to ascertain changes in the coastline, extensive photography and observations to help determine the composition of the shorelines, and weather information to monitor changes in the local climate.

Feature/Target Detection & Recognition

A secondary aim of the study is feature and target detection and recognition in arctic environments. This takes advantage of the many features and targets that were ground truthed in and around Alert (Figure 1). These features/targets include a runway and airfield (Figure 5), a variety of roads, fuel reservoirs, pipelines, pumping stations, antennas, cairns, three airplane crash sites, and a variety of buildings. Extensive photographic and observation records were collected during the spring and summer missions to Alert (see Appendix C and D for a listing of photographs). This study seeks to develop and test tools and techniques based on InSAR for feature detection and recognition. Using RADARSAT 2, this experiment should be extended to take advantage of the polarimetric as well as polarimetric interferometric capabilities of this satellite. Both technologies should provide useful tools for feature/target detection and recognition.

Experimental Site

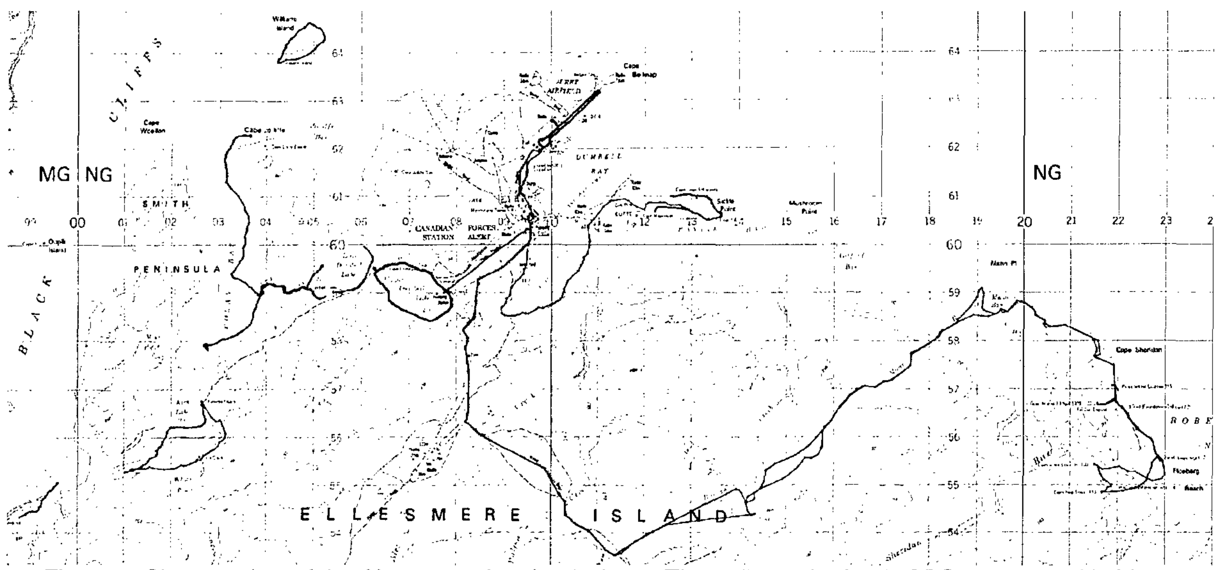

Figure 1: Site overview of the Alert ground truth missions. The trails tracked with GPS are marked in blue.

Alert is located on the north coast of Ellesmere Island in Nunavut. It is said to be the most northern permanently inhabited settlement in the world. Alert was first settled in early 1950s as a joint Canada/US weather station. The Canadian military station was established in 1958. During the Cold War it was Canada's most important intercept station for monitoring the Soviet Union. There are a variety of intercept antenna arrays on the station.

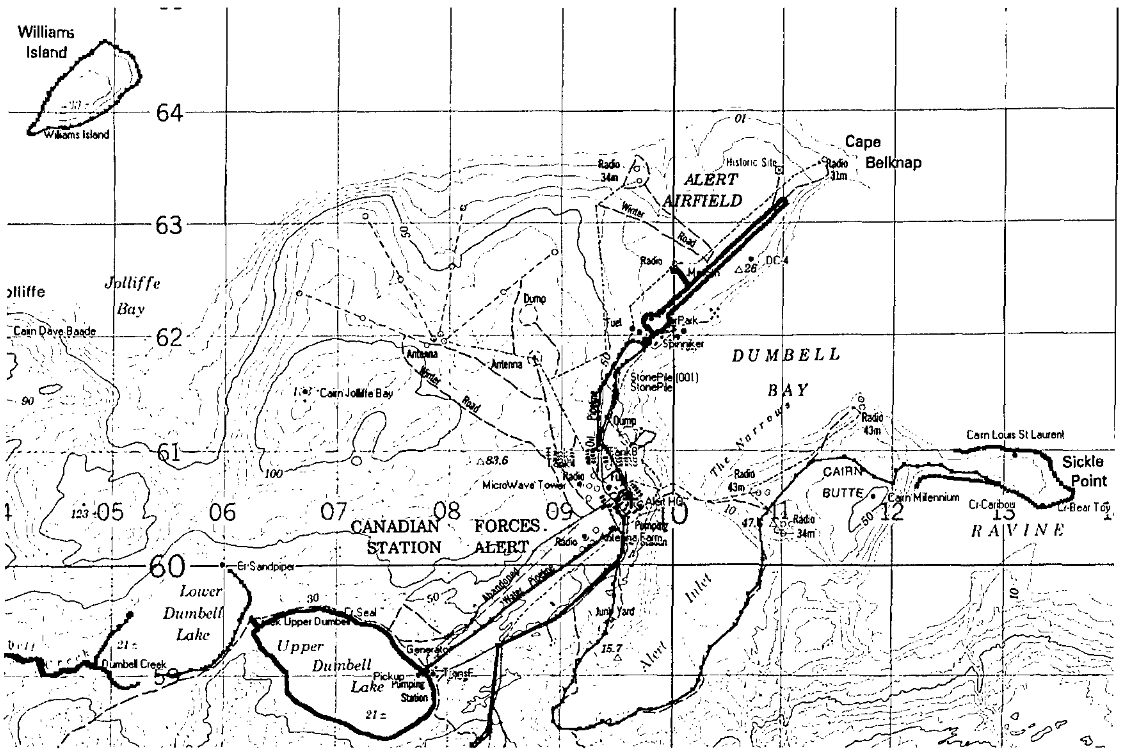

Figure 2: Detailed map of the site of the Alert ground truth missions. The trails tracked with GPS are marked in blue.

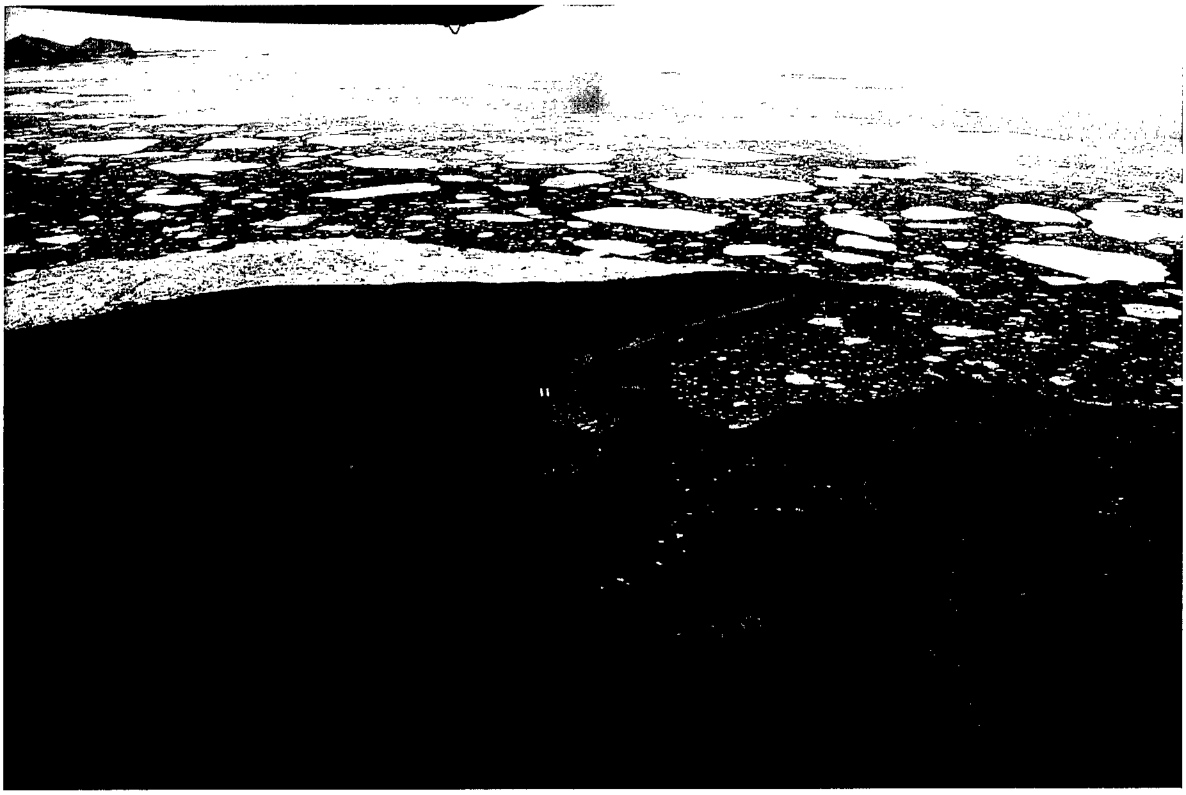

Figure 3: Aerial photograph of Alert taken from the aircraft window by J. Lang on 31 July, 2002 [DRDC Ottawa PHOTO 02-8501].

CFS Alert was a target of opportunity. Figure 1 shows an overview of the site of the ground truth site in and near Alert. Figure 2 provides a detailed view of Alert itself. Figure 3 shows an aerial view of CFS Alert, captured by J. Lang on 31 July 2002. A number of experimental missions from DRDC Ottawa have used Alert as a test site for a number of years. In the spring and summer of 2002 we piggybacked on two such missions to collect extensive ground truth at little expense to ourselves.

For the purposes of this experiment, Alert and its environment contain a variety of features and targets central to accurate mapping and Geographic Information System (GIS) databases. With respect to shoreline delineation, it contains a variety of coastlines, including a number of islands, lakes, and river and drainage networks. With respect to man-made features/targets, it contains a runway and airfield, a variety of roads, fuel reservoirs, pipelines, pumping stations, antennas, cairns, three airplane crash sites, and a variety of buildings. The variety of features make this site very suitable for this Arctic mapping experiment.

Figure 4 shows an aerial photograph of Alert captured on 31 July by J. Lang. To the left of the centre is the airfield. Just below centre are 8 fuel tanks. To right of centre are the buildings housing the personnel resident at Alert. Figure 5 captures the Alert airport complex, including the runway, fuel depot, and CC-130 Hercules aeroplane, and in the bottom central portion of the picture, the weather station is visible.

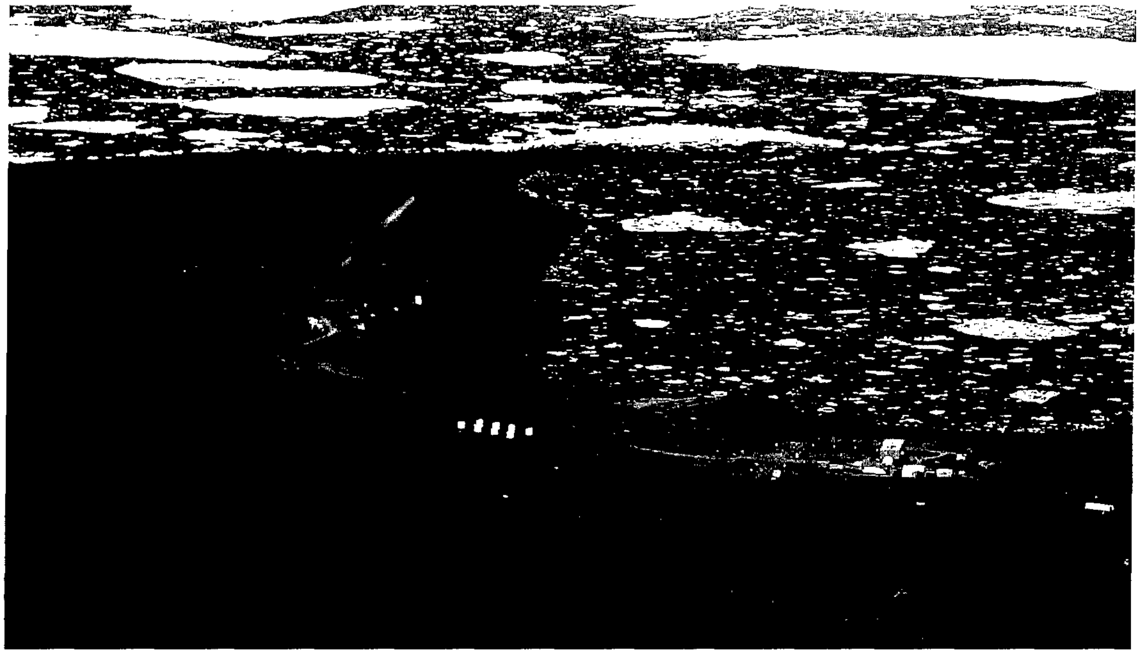

Figure 4: Aerial photograph of Alert taken by J. Lang on 31 July, 2002 [DRDC Ottawa PHOTO 02-8548].

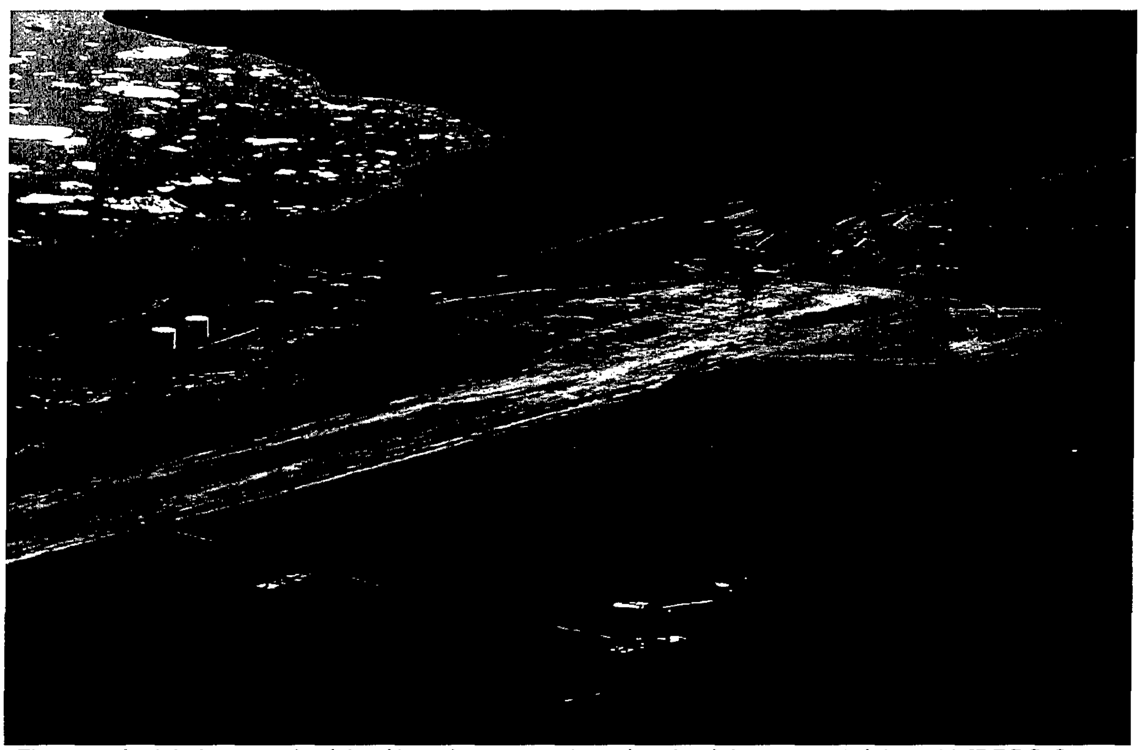

Figure 5: Aerial photograph of the Alert airport complex taken by J. Lang on 31 July 2002 [DRDC Ottawa PHOTO 02-8580].

RADARSAT Data Acquisition

Several RADARSAT pairs suitable for interferometric processing were collected to coincide with both the spring and summer ground truthing missions. These are listed in Table 1 by pair. Also included in the table is the start time (in GMT) of the image frame, the RADARSAT mode, the incidence angle at scene centre, the pass orientation, the orbit number, and the number of corner reflectors (CRs) visible in the scene. All the images were acquired in fine mode with an azimuth resolution of approximately 8.4 meters and a ground range resolution ranging from approximately 7.8 meters (beam position F4F) to 8.8 meters (beam position F1F) at scene centre (equivalent to a slant range resolution of 5.6 meters). The azimuth resolution may deteriorate slightly after interferometric processing. The azimuth pixel spacing is approximately 5 meters. The ground range pixel spacing varies from 6.5 meters to 7.3 meters at scene centre (equivalent to a slant range spacing of 4.6 meters).

Table 1: *RADARSAT interferometric pair acquired over Alert during the 2002 trials*

Interferometric Pair (2002)	Day of the Year (2002)	Start Time (GMT)	Beam Position	Incidence Angle at Scene Centre (degrees)	Pass	Orbit #	Number of Visible Corner Reflectors
Mar 23	082	12:00:50.669	F1F	39.232	Desc	33313	0
Apr 16	106	12:00:49.789	F1F	39.232	Desc	33656	0
Apr 13	103	11:48:21.211	F2F	41.475	Desc	33613	4
May 7	127	11:48:15.295	F2F	41.475	Desc	33956	4
Apr 20	110	11:44:07.243	F2F	41.479	Desc	33713	0
May 14	134	11:44:04.704	F2F	41.479	Desc	34056	4
Jul 27	208	20:45:46.909	F3F	43.412	Asc	35119	0
Aug 20	232	20:45:42.970	F3F	43.412	Asc	35462	0
Jul 30	211	20:58:19.350	F4F	45.275	Asc	35162	2
Aug 23	235	20:58:23.750	F4F	45.275	Asc	35505	0
Aug 4	216	11:52:20.004	F2N	40.060	Desc	35228	4
Aug 28	241	11:52:18.368	F2N	40.060	Desc	35571	0
Aug 5	217	11:23:01.703	F4N	44.126	Desc	35242	2
Aug 29	242	11:22:59.958	F4N	44.126	Desc	35585	0
Aug 8	220	11:35:34.371	F3	42.809	Desc	35285	0
Sep 1	244	11:35:33.357	F3	42.809	Desc	35628	0
Oct 30	303	11:15:30.38	F5		Desc		0
Dec 6	340		F5		Desc		0
Dec 17	351	11:15:30.38	F5		Desc		0
10 Jan '03	10	11:15:30.38	F5		Desc		0

The ascending passes were downloaded in real-time using the antennas operated by the Alaska SAR Facility (ASF). The descending passes had to rely on the on-board tape recorders for delayed downlink to the Gatineau station. In general we experienced many difficulties in collecting RADARSAT data over Alert. In total 13 passes were lost due to satellite anomaly, conflicts with higher priority acquisitions, or full on-board tape recorders.

Some passes had to be cancelled due to the loss of their interferometric mate. Plans to acquire interferometric triplet also had to be cancelled for the same reason. Four more acquisitions have been requested for 30 October 2002, 23 November 2002, 17 December 2002, and 10 January 2003. These should all be suitable for interferometric processing. With these additional acquisitions, we will have RADARSAT images covering almost an entire yearly cycle.

To date, all pairs of data acquired, with the exception of 30 July/21 August, have been successfully processed to the interferogram stage. The 23 August data sets collected by ASF had some formatting discrepancies. Processing of the data to Single Look Complex (SLC) failed using both Atlantis' Advanced Precision Processor (APP) and MacDonald Dettwiler and Associates' (MDAs) "PGS" software. RADARSAT International (RSI) processed the image for us using "CDFP". The resulting SLC had a different pulse repetition frequency (PRF) than its interferometric mate, an occurrence that I have never encountered. Distortions occurred in range, and covered 35% more ground in near range. It was concluded that an error occurred during image acquisition; therefore, attempts to interferometrically process the pair were abandoned.

Ground Truth

During the two missions to Alert in the spring and summer of 2002, extensive ground truth in Alert and its environment was collected. The spring field mission took place between 11 April and 8 May. The team was composed of Lloyd Gallop, Janice Lang, and Jim Milne. The summer field mission took place between 23 July and 8 August. The team was composed of Lloyd Gallop, Janice Lang, and Al Tremblay. The ground truth consisted of GPS track measurements of shorelines, trails, roads, pipelines, and the runway. It also consisted of GPS waypoint measurements of corner reflectors, permanent scatterers, and targets of opportunity. Extensive photographs were taken of a wide variety of potential targets of interest from both the ground and the air. In additional tidal measurements were collected, and weather data were obtained. Throughout the trip personal notes were taken. These provide additional valuable insight.

Figure 6: A corner reflector being deployed along the southern edge of Sickle Point in the Spring of 2002 [DRDC Ottawa PHOTO 02-1935].

GPS Measurements

Geolocation using the Global Positioning System (GPS) figured prominently in these missions. Both individual targets as well as trails were measured by this means. Individual targets consisted of corner reflectors that were deployed for the occasion, and targets of opportunity. Appendix B lists the targets and scatterers measured. The trails measured consisted of coastlines, lake shorelines, as well as roads and pipelines. Appendix A lists the trails measured.

Corner Reflectors

To help with the interferometric calibration and mapping, several GPSs were measured. These GCPs consisted of corner reflectors and permanent scatterers. During both spring and summer trials, four corner reflectors were deployed in the scene. Their positions were measured using the global positioning system (GPS). During the spring trials, the four corner reflectors were deployed along the southern coast of Sickle Point at the shore and ice interface, at 250 metres intervals. Figure 6 shows one of these corner reflectors being deployed. Figure 7 shows how the 4 corner reflectors appear in the radar image. The reflectors were deployed on 13 April, and removed after the last spring RADARSAT pass on May 14.

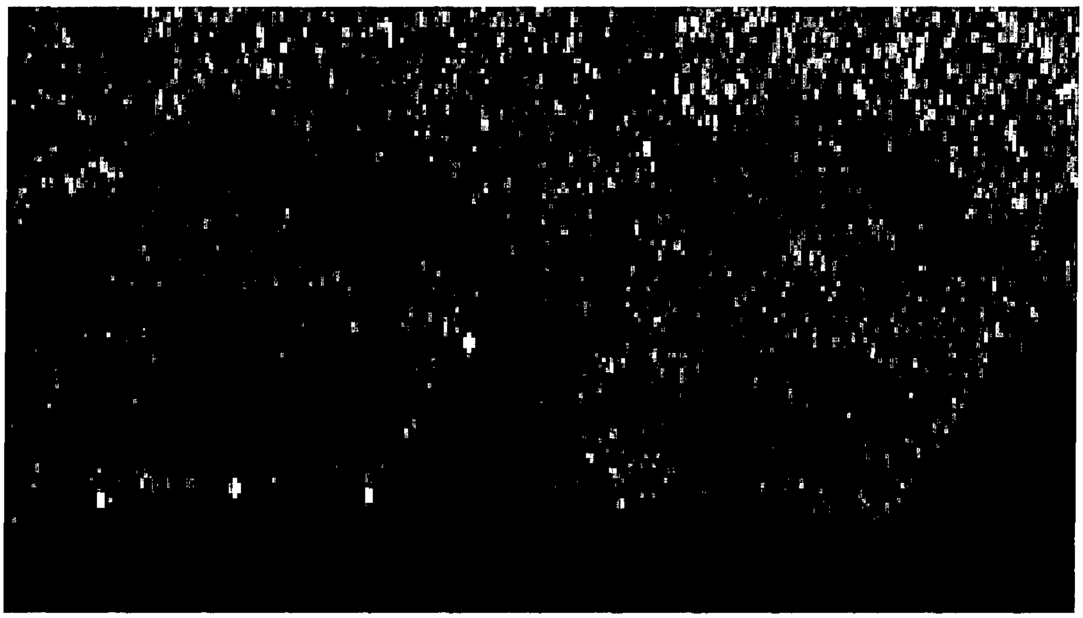

Figure 7: Corner reflectors as they appear in the radar image. The image on the left is from 7 May 2002; the image on the right is from 20 April 2002.

Deploying the corner reflectors was quite basic. A series of holes were dug perpendicular to the shoreline to identify the shore and ice interface. The corner was then placed on the snow surface at the interface. With a hand held GPS receiver a bearing was paced parallel to the corner's face adjusting the corner in iterative steps until the required azimuth angle was achieved. To verify the orientation, the corner bore sight to the satellite was paced to determine a GPS bearing, equivalent to the corner face azimuth angle plus 90°. The corner outline was then traced in the snow so that the snow could be removed is such a way to let the corner drop in with the appropriate elevation. With the elevation adjustment complete, the front face of the corner was levelled. Finally the corner backside was banked with show. Waypoints and other parameters for each of the corners were determined and noted.

A listing of the RADARSAT passes in which the corner reflectors are visible is given in the last column of Table 1. While the deployment of the corner reflectors were not difficult, it was difficult to maintain their position and visibility. Polar bears seemed to be attracted to the corner reflectors, perhaps because of their red colouring. A few corners were displaced by bears and had to be redeployed. A larger challenge was snow accumulation in the corners during strong windstorms. The snow was sufficiently compacted in the corner to cause near total obscuration of the radar return (as in the right image of Figure 7).

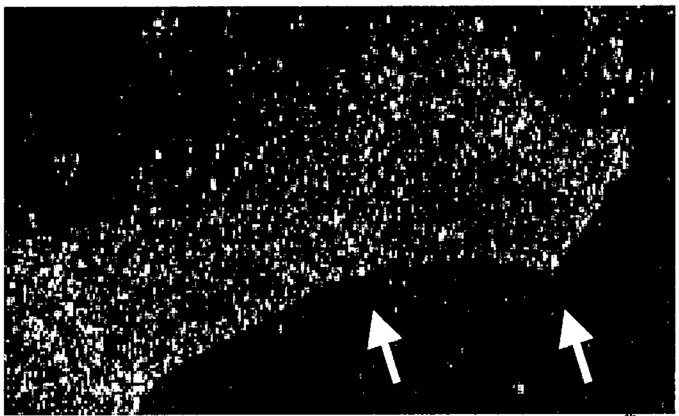

Figure 8: Two Corner reflectors as they appear in the 4th August RADARSAT image along the shoreline of Sickle Point.

During the summer trials 2 corner reflectors were deployed along the southern coast of Sickle Point at the same location as in Spring (see Figure 8). These were separated by 500 metres, and were placed 3 metres (Sickle Point west) and 3.38 metres (Sickle Point east) from the coastline at high tide, but below the surge line. The other two corner reflectors were deployed along the shores of the Upper (Figure 9) and Lower Dumbell lakes, 1.83 and 4.27 metres from the lake shoreline, respectively (see Figure 10).

Figure 9: A photograph, taken by J. Lang on 27 July 2002, of the corner reflector deployed along Upper Dumbell Lake [DRDC Ottawa PHOTO 02-7917].

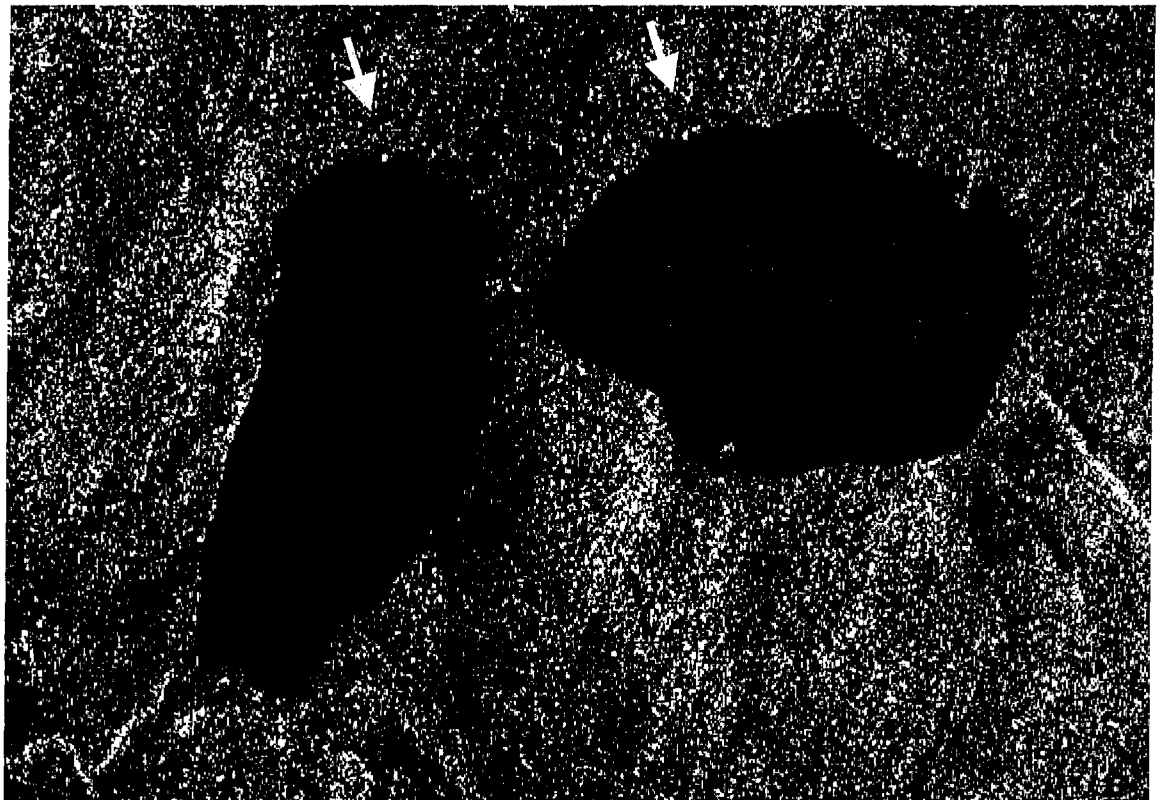

Figure 10: Two Corner reflectors as they appear in the 4th August RADARSAT image along the shorelines of the Lower (left) and Upper (right) Dumbell lakes.

The location of these four corner reflectors provided for a larger separation in range than previously; therefore they were better suited for interferometric calibration of the data. They also provided a reference for the two Dumbell lakes. Rocks were used to properly level the corners, and to support their backside. Deployment and measurement of the position of corner reflectors proceeding as previously described. More extensive information about deployment of the reflectors is available from the personal notes of Lloyd Gallop.

Permanent scatterers and targets of opportunity

Alert and its environment provided for many readily available corner reflectors, or as they have been called in the InSAR literature, PSs. The position of many of these PSs were measured and photographed in an effort to provide additional data samples for geometric calibration and geocoding, as well as for providing information for target recognition. A complete list of the measured permanent scatterers is included in appendix B. Most of the PS are man made structures.

Among these scatterers is a tank farm consisting of 8 tanks (Way Point ID 68-75; shown in Figure 4) surrounded by a 2 m berm of approximately1 meter. The tanks are laid out in two rows of four. Each tank is 9.145 meters in diameter, 7.315 meters high, and holds 480,477 litres of fuel. All geo-positions were taken from the tank's access ladder. A 4.5" pipeline runs 18 to 24" above the ground towards the airstrip for an unknown distance before running underground. Other targets of opportunity in Alert were an old Lancaster crash site, a Hercules aircraft (ID 338) delayed at the Alert airport from July 25 to August 2, metrological sensors (ID 83) and shack (ID 84), an air crash monument of 31 July 1950, and the Spinnaker building.

A few targets of opportunity were located at the site of the station's water system on Upper Dumbell Lake. These consisted of a fibreglass clad intake building (ID 82), a transformer platform (ID 80), a wooden structure (ID 79), and the metal generator building (ID 81).

Others prominent land features were located with GPS. These include, for example, Mushroom Point, Sickle Point, Williams Island, Oopic Island, and a small unnamed island in Upper Dumbell Lake. Some of these targets may be a challenge to recognize or detect with the fine beam images collected with RADARSAT-1; however they serve as a valuable record for reference, and will be useful for future sensors such as RADARSAT-2.

Coastlines & Shorelines

In fulfillment of the shoreline delineation objective of this mission, GPS was used to track a variety of shorelines, coastlines, and river networks. Figure 1 provides an overview of the Alert area. Figure 2 provides a detailed view of Alert itself. In both figures the trails tracked with GPS are marked in blue. These include the coastline along Sickle Point where the corner reflectors were deployed, and the east side of Colan Bay from Kirk Creek to Cape Jolliffe. They also include parts of the Upper and Lower Dumbell lakes, the perimeter of Williams Island (spring only), and portions of several ravines and rivers in the area. All of these shorelines are documented photographically as well.

Roads, Runways, Pipelines

Several trails of opportunity were also tracked. The variety of types and qualities of roads photographed and tracked provides an important source of information for – winter and summer – feature extraction and recognition. All of the tracks were also photographed at least once to reveal setting and details. These tracks include the runway with the service roads on each side. The runway is 50 m wide, and composed of compacted, crushed stone and stone dust. Each service road is 11 meters wide. Another track followed the north road from the Spinnaker Building to the tank farm, and the return on the south side. This road is 10.7 meters wide, with hard packed stone on a clay base with approximately 1 mete drops on each side to handle water runoff. A third track followed some of the main roads in Alert.

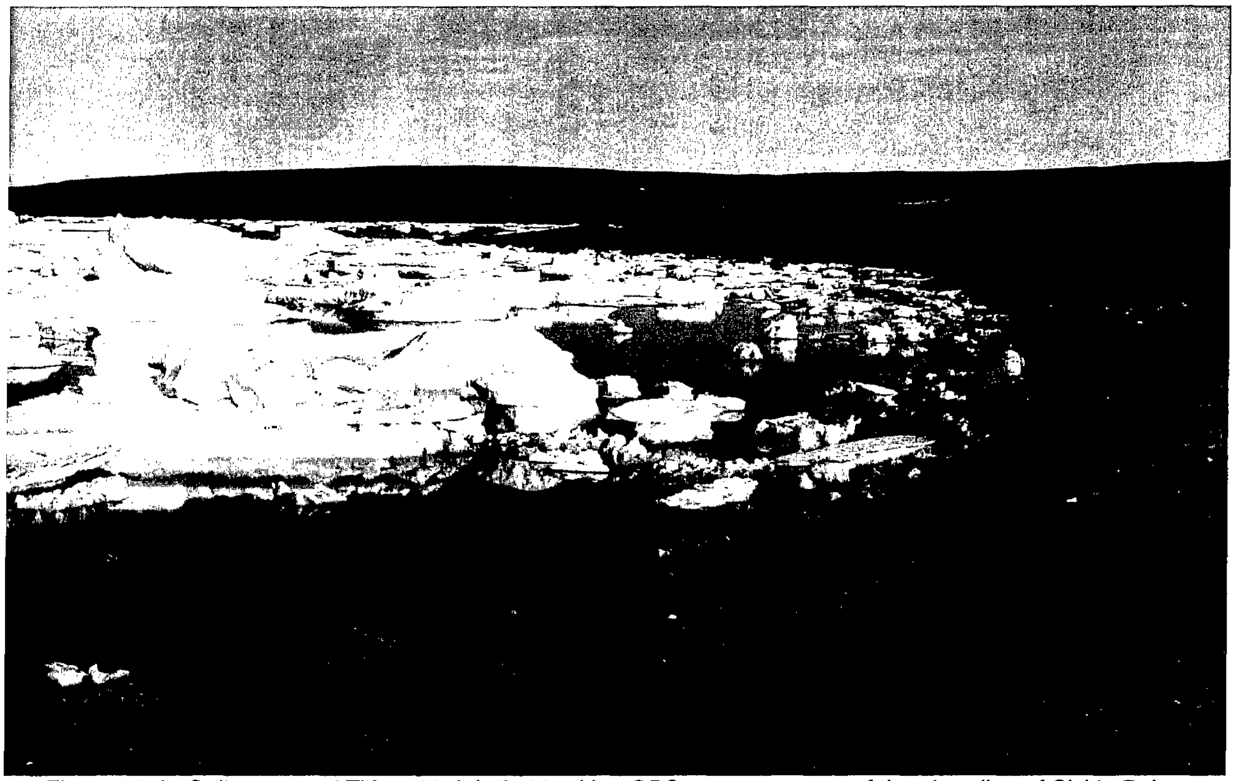

Figure 11: L. Gallop on an ATV on 30 July 2002 taking GPS measurements of the shoreline of Sickle Point [DRDC Ottawa PHOTO 02-8369].

Photographic documentation

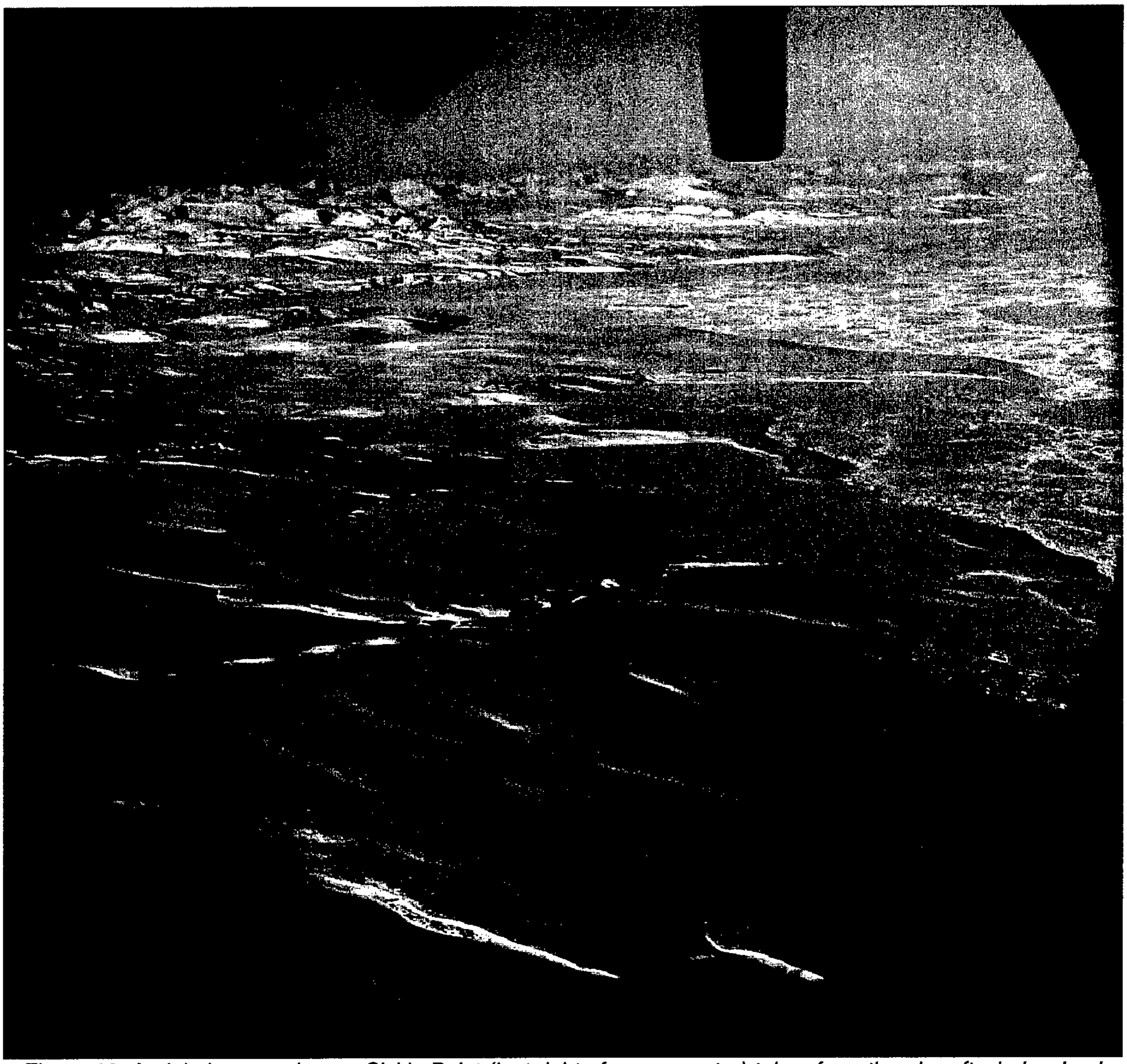

Figure 12: Aerial photograph over Sickle Point (just right of scene centre) taken from the aircraft window by J. Lang, Spring 2002 [DRDC Ottawa PHOTO 02-0309].

An extensive photographic documentation was acquired during both the spring and summer missions. Janice Lang took the majority of the pictures; however, L. Gallop acquired some as well. All these pictures are available upon request from DRDC-Ottawa. Notes accompany some of the pictures, and are also available on request. Appendix C includes a list of photographs acquired during the summer 2002 trials.

Aerial

Only a few aerial photographs were acquired over Alert during the spring mission. Figure 12 is the best examples of these. It shows Sickle Point and Cairn Butte in scene centre, and the

Alert runway in the background. A larger number of aerial photographs, with a wide variety of viewpoints, were collected during the summer mission.

Ground

An extensive photographic record of Alert and its environment taken from the ground is available for both the spring and summer missions. These photographs provide a complete record of the permanent scatterers and trails measured with the GPS. They also provide an invaluable detailed record of the composition of the shoreline and trails including the presence of icebergs beached along the shoreline, and many other objects of potential interest. A good example of the shoreline composition is shown in Figure 13. The photograph was taken in the spring of 2002, at the saddle on Smith Peninsula, just north of the narrows in Colan Bay. Wind storms, common to this area, have swept snow and soil from the ground and caused them to penetrate into the snow cover on the ice of the bay. This phenomenon may have a distinct effect on the radar return.

Figure 13: This photograph was taken in the spring of 2002, at the saddle on Smith Peninsula, just north of the narrows in Colan Bay [DRDC Ottawa PHOTO 02-3734].

Tide

According to DTED standards shorelines should be referenced to the Mean High Water Level (MHWL). By definition, the MHWL is the horizontal vector shoreline referenced to the maximum high tide elevations averaged over nineteen years. So the distance between the MHWL and the in-situ waterline is dependent of the tidal stage and daily tidal variability.

Depending of the changes in the local tide and the local shoreline slope, the location of a given shoreline can vary significantly and continually. The interferometric phase reflects the difference between the tidal states of both acquisitions. For these reasons tidal information is obviously very important in shoreline delineation. During this ground truth mission tidal models were obtained for Alert, and compared with local tidal variation measurements.

In August 2002 the Canadian Hydrographic Services (CHS) installed a permanent Tide Gauge at the inside narrows of Alert inlet to measure tide currents and water levels.

Predicted

Figure 14 shows the predicted tide for Alert for the duration of the spring (top) and summer (bottom) trials, courtesy of the Department of Fisheries and Oceans (DFO). The red stars denote RADARSAT acquisitions. The black lines connecting pairs of stars denote interferometric pairs.

The tide in all cases is less than 1 metre. In InSAR it is the difference in the tidal level between the two acquisitions that is observed, and reflected in the phase and coherence information.

Measured

In view of gaining a measure of confidence in predicted time, tidal data was collected in Ravine Bay on the Sickle Point shoreline on August 4, 2002. One end of a 16-foot 2"x4" stick was anchored in the water at approximately low tide, with the other end anchored on shore above the high tide line. The slope angle was then measured (15.5 ±0.2°) and the distance to the waterline was determined every 20 minutes for 6 hours. These measurements did not include a height reference so all measurements are relative. Calculations were made to determine the horizontal and vertical components from the slope to generate Figure 15.

The triangular data points on the graph were extracted from a model data set provided by Ron Solvason of CHS (Feb 02). The raw data set fits to approximately 1 cm while the model fits to better than 0.1 cm. The relative height difference for the two data sets is 5 cm. Note that the time line between these two data sets had to be adjusted for daylight savings. Finally the tide amplitude levels on Aug 04th were at a minimum relative to a few weeks before and after these measurements.

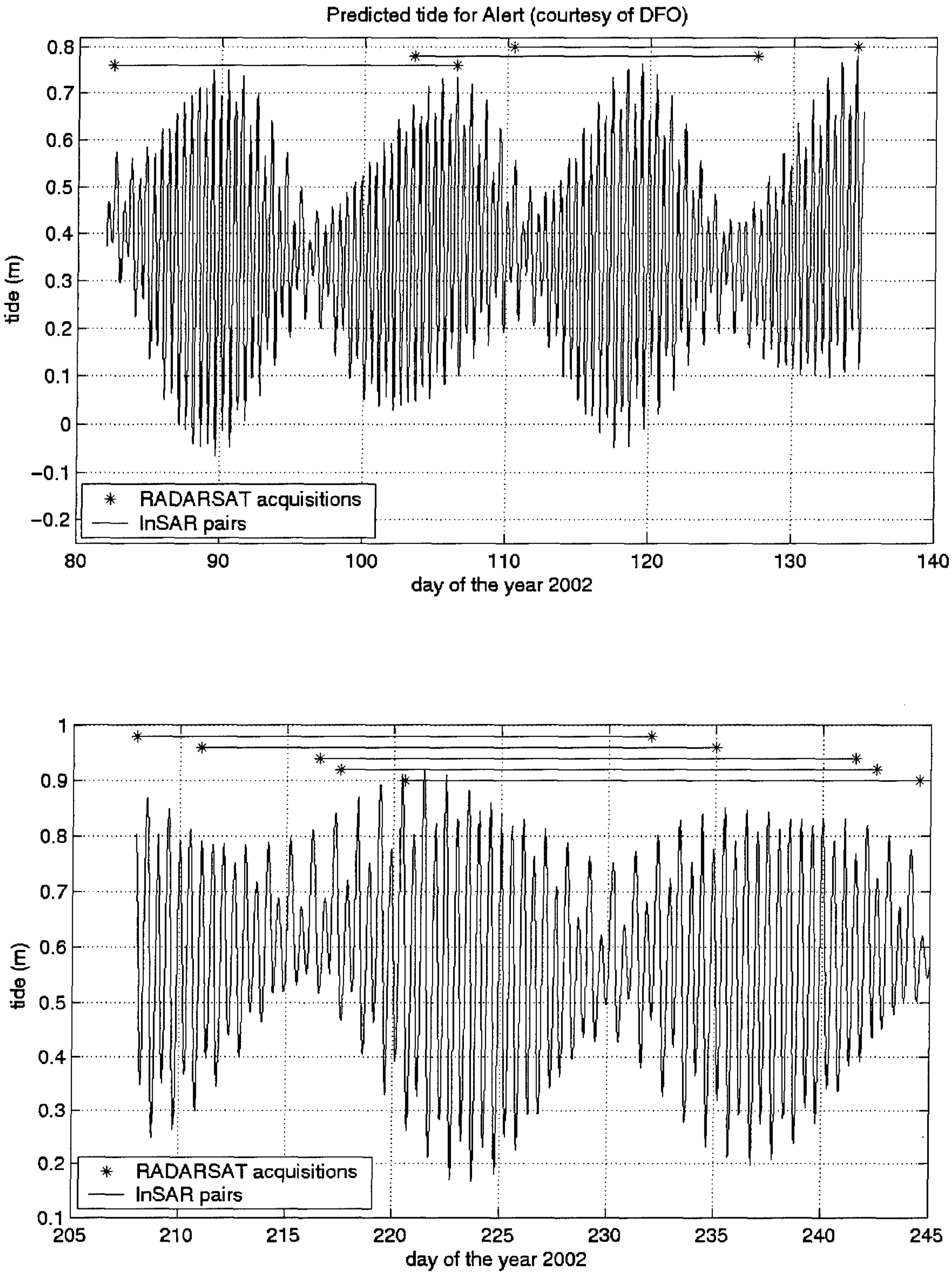

Figure 14: Predicted tide for Alert duringf the spring (top) and summer (bottom) trials (courtesy of Department of Fisheries and Ocean, DFO).

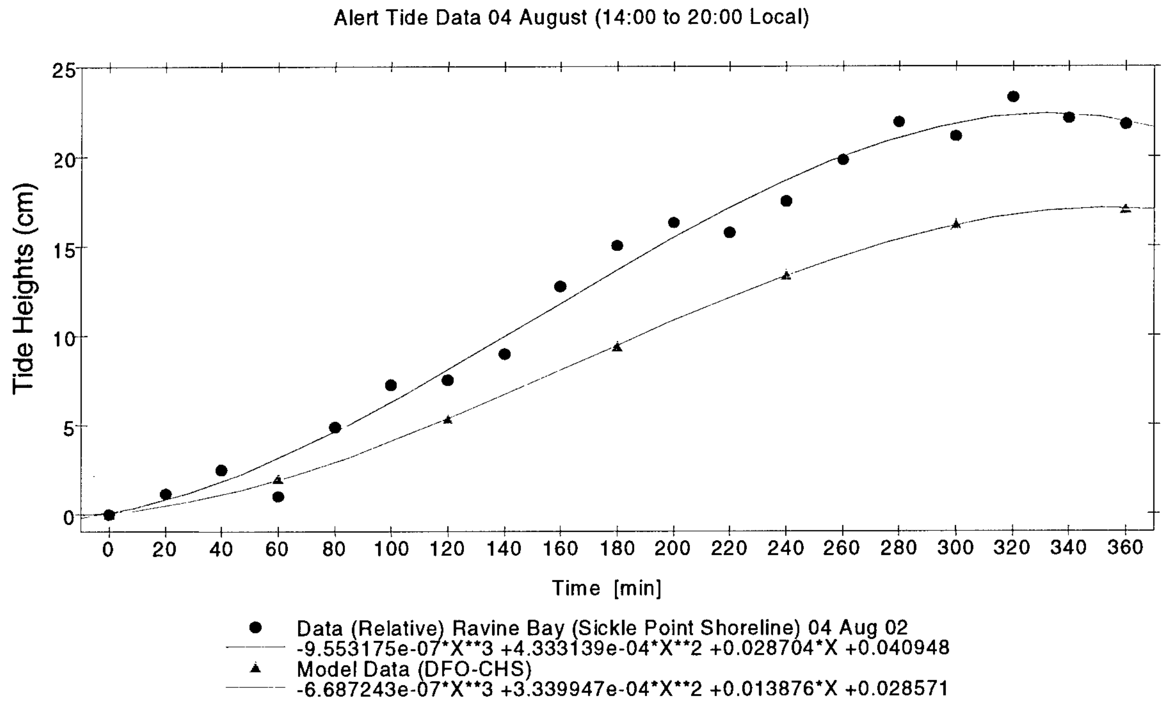

Figure 15: Measured versus predicted relative tide for Alert on 4 August, day 216 of the year 2002.

Weather

Weather effects can significantly impact conditions on the ground, especially in a location such as Alert, where the climate is quite harsh. They also can have a significant impact on radar backscatter images as well as on the interferometric coherence and phase. Among the most significant weather parameters are temperature, and wind. As the temperature falls below freezing, rivers, lakes, and, eventually oceans freezes. During the summer months sea ice drifts in the direction of the wind. Depending on the wind speed and direction sea ice can beach itself along the coast, or drift far a field. Figure 16 is a photograph of several icebergs that were beached along the shoreline of Sickle Point on July 30, 2002. During the winter or spring months, strong winds can cause drifting snow which directly impacting radar backscatter, and may detrimentally affect the interferometric coherence and phase.

Figure 16: L. Gallop on the shoreline of Sickle Point on 30 July 2002 in front of beached icebergs [DRDC Ottawa PHOTO 02-8416].

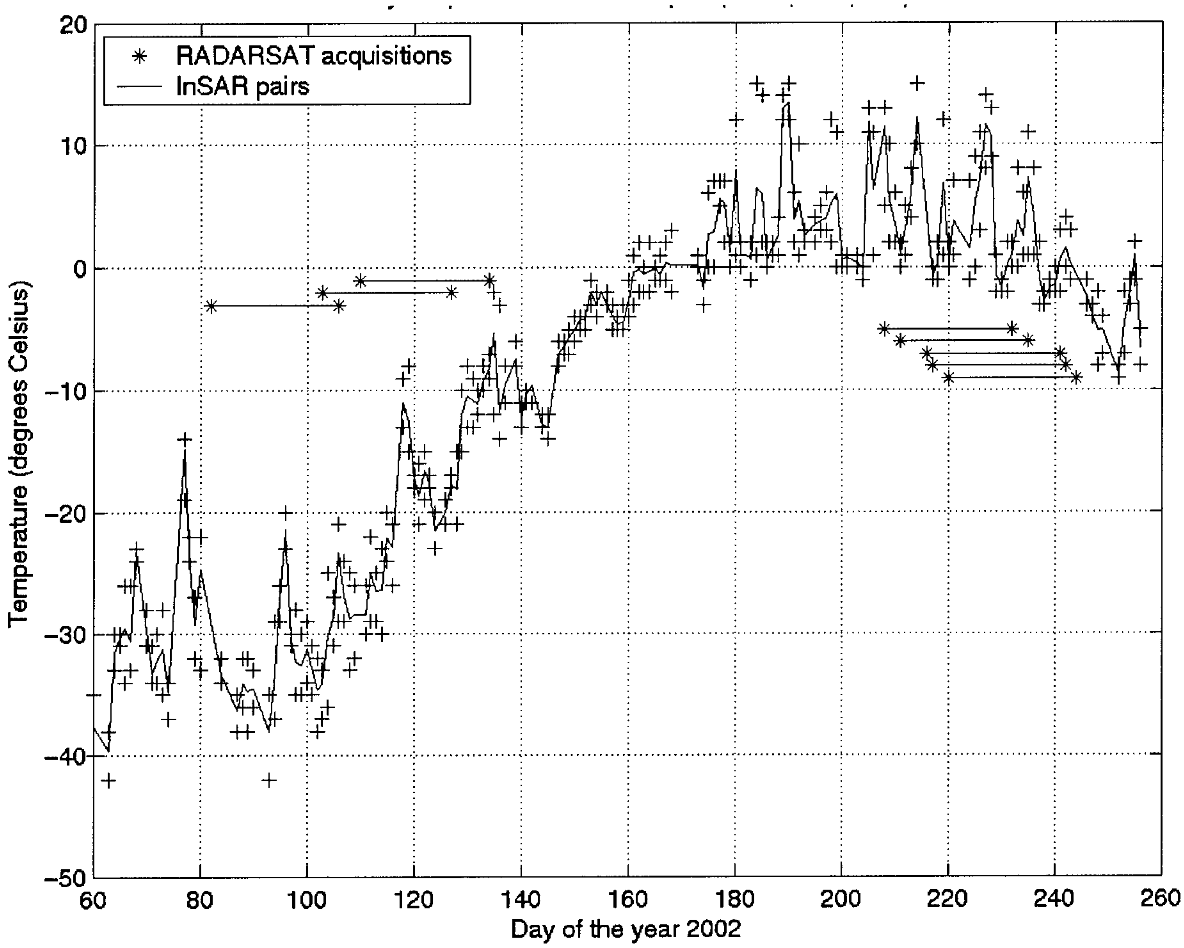

Figure 17: Temperature data from Alert Airport (mean, maximum, minimum).

Precipitation did not seem to be a significant factor this year. People on site testified that summer of 2002 was very dry in Alert. During the spring months drifting snow seemed to have a more significant impact on the terrain, and consequently on radar interferometry than precipitation. For these reasons, and because a consistent record of precipitation was not available, precipitation is not one of the weather parameters provided here.

The temperature and wind speed collected at Alert Airport for the duration of the spring and summer mission of 2002 is shown in Figure 17 and Figure 18, respectively. Figure 17 delineates the mean daily temperature, with the daily maximum and minimum indicated by the '+' sign. Figure 18 delineates the mean daily wind speed, in knots, with the maximum sustained with speed indicated by the '+' sign. The red stars denote RADARSAT acquisitions. The black lines connecting pairs of stars denote interferometric pair.

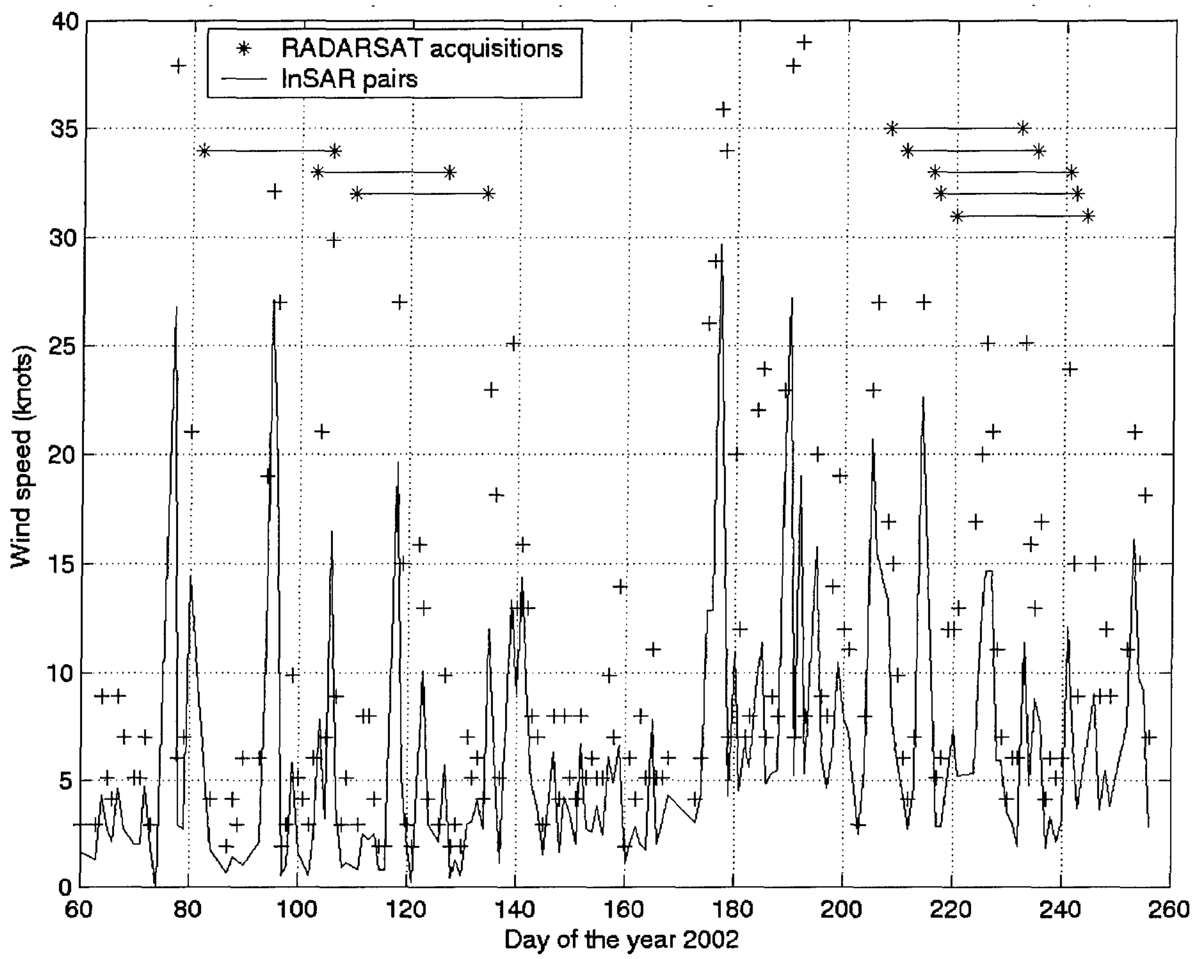

Figure 18: Daily mean wind speed data for Alert Airport, including maximum sustained wind speed.

Conclusion

In the spring and summer of 2002 an opportunity arose to collect extensive ground truth in and around Alert, Nunavut. This consisted of extensive photographic documentation, GPS measurements of shorelines, riverbanks, and roads, GPS measurement of GCPs and targets of opportunity, tidal measurements and comparisons with tidal models, and weather data collection. In conjunction with the ground truth, eight interferometric RADARSAT pairs were collected. This data will form part of a study into shoreline delineation and feature/target extraction using InSAR. The purpose of this memo was to document the ground truth and radar images collected, so others may make use of this data for other studies.

References

1. M. Yeremy, A. Beaudoin, J.D. Beaudoin, G.M. Walter, "Global shoreline mapping from an airborne polarimetric SAR: assessment for RADARSAT 2 polarimetric mode", DRDC Ottawa Technical Report DREO-TR 2001-056.

2. K.E. Mattar, M. Buchheit, & A. Beaudoin, "Shoreline mapping using interferometric SAR", DRDC Ottawa Technical Report DREO-TR 2001-078, October 2001.

List of symbols/abbreviations/acronyms/initialisms

ASF	Alaska SAR Facility
CFB	Canadian Forces Base
CFS	Canadian Forces Station
CHS	Canadian Hydrographic Services
CR	Corner Reflector
DEM	Digital Elevation Model
DFO	Department of Fisheries and Oceans
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DREO	Defence Research Establishment Ottawa
DTED	Digital Terrain Elevation Data
EPE	Estimated Position Error
GCP	Ground Control Point
GIS	Geographic Information System
GPS	Global Positioning System
InSAR	Interferometric SAR
MDA	MacDonald Dettwiler and Associates
MHWL	Mean High Water Level
NIMA	National Imagery Mapping Agency
PS	Permanent Scatterers
RSI	RADARSAT International

SAR	Synthetic Aperture Radar
SLC	Single look complex

Appendix A: List of GPS tracks measured in & near Alert, spring & summer 2002

No.	File	Comments
1	AirStrip29Jul.txt	The track was driven on the inside of the runway lights, first leg was NE to the end of the runway across the end and down the North side and around the service apron. Spot 1 was not recorded due to a Hercules being serviced on that location. On either side of the runway there is a service road, which will add to the runways apparent width. Each service road is 11 meters and the runway is 50 m for a total width of 72 meters. In addition waypoints for the Met Shack and Sensor tower were recorded.
2	AirStrip05Aug.txt	During the evening of August 5, a complete GPS track of the airstrip and the aircraft parking apron. The GPS track includes the full width of the runway; this means that the runway service roads were included in the width of the airstrip. This track includes a jog into the Met Station on the north side of the runway and a trace around the backside of the Spinnaker building.
3	ColonBayLDBCreek.txt	GPS track of the South end of Colan Bay from Kirk Creek via Dumbell Creek to Lower Dumbell Lake.
4	DumbellWaterLine.txt	A water intake building projecting into Upper Dumbell Lake, a generator building, and a transformer platform supports the station water system. A wood structure is also co-located in this area. The intake building is fibreglass clad and measures 34' x 24' x12'. The generator building is metal clad and the fourth building is constructed of wood. The water line from the intake building runs in two parallel lines on the ground up the hill to the station with 45 gallon barrels beside the line every 7 to 10 meters. A GPS track of the line was measured from the lake to the station.
5	FloebergBeachTrip.txt	This GPS track was generated during an ATV trip form CFS Alert HQ to Floeberg beach and back. There was a battery failure noted on the outbound track at Self Pond. This track is included because in covers a number of interesting segments. These segments include roads and BV trails south of Alert to Ravine Creek, and then follows Ravine Creek to approximately Self Pond, next across country to Mann River. The Mann riverbed is then traveled to Mann Bay where the coastline is picked up and followed South to Cape Sheridan and then on the Floeberg Beach. A number of large Cairns visited as well as the foundation remains of Peary's winter over quarters.
6	HilgardHike29Jul.txt	Hike from the Hilgard Bay lookout back to vehicle at east of Hollins Creek delta.
7	HQtoSpinkr24Jul.txt	GPS track from CFS Alert main buildings to Spinnaker building and back.
8	JP8Pipeline.txt	This track follows the station JP8 fuel line from the storage tanks northeast down to the Spinnaker building. The station tank farm is ~500 m northwest of the station's main complex. The farm consists of 8 tanks surrounded by a 2 m berm of crushed stone. Inside the main berm each tank is isolated from the other by a smaller berm ~1 meter. A 4.5" pipeline runs underground from near Spot 1 on the airstrip across the southwest end of Spinnaker where it rises to 18 to 24 inches above ground and then up the hill to the tank farm. The tanks are laid out in two rows of four. Each tank is 9.145 meters in diameter (38 paces), 7.315 meters high and holds 480477 litres. All Geo-positions were taken from the tank's access ladder. The track on the pipeline was walked and recorded (distance 1.2 km).
9	KirkCreektoHQ.txt	This track covers the trail from Kirk Creek near the ice cave back to Alert HQ the night that Al was Hurt.
10	KirkLakeIceCave.txt	This track is a combination of Friday night's (02 August 02) return from the cairn lookout south and above Kirk Lake and a second hike on Saturday morning starting from the Kirk Lake Hut up the creek bed to the Ice Cave through the tunnel and along the ridge to the cairn east of White Pond, then down over the Kirk Lake Wall to the BV track and back to the Hut.
11	LDBCreekColonBay.txt	This track runs from Lower Dumbell through Dumbell Creek to Colan Bay and along the east side of the bay to the north end at Cape Jolliffe.

12	LDBCreekWest.txt	A partial GPS track of the Lower Dumbell shoreline from the Sandpiper Corner to the May Creek Delta (where I got the Quad stuck in the mud).
13	LoDumbellExitA.txt	Track data for west end of Lower Dumbell Lake showing Dumbell Creek exit for Colan Bay.
14	LowerDumbellWest.txt	Partial GPS track of Lower Dumbell Lake from Sandpiper Corner west (CCW) to rock wall. Safety did not permit any further travel along the shoreline.
15	RoadTankstoSpinkr.txt	The track of the road from the Spinnaker building to the tank farm was walked and recorded on the north side of the road and the return on the south side was driven on the Quad. The road is hard packed stone on a clay base with ~1-meter drops on each side to handle water run off. The road width is 10.7 meters. There are two large crushed stone piles on the south side of the road (wpt 77 and 78) wpt 77 is the larger of the two piles.
16	SicklePointTrack.txt	This is the complete GPS track log of Sickle Point tracing clockwise along the north side around the point and back along the south side at low tide on 30 July 2002.
17	UpperDumbellLake.txt	This is a complete track of Upper Dumbell Lake starting from the Water pumping station and traveling clockwise around the lake. On the south side of the lake the track is approximately 2-meters from the shoreline due to the slope and roughness of the shore, while on the north side of the lake the track is 0.5-meters in the water due to the characteristics of the shoreline. A short jog was taken in the lakes shoreline to define the creek exit to Lower Dumbell Lake. Do not forget that this has been a very dry summer with significant winds in the Alert area; this implies that the fresh water shorelines are probably lower than usual.
18	UpperDumbellLaketoHQ.txt	Track for Upper Dumbell Lake from short creek that joins Upper and Lower Lakes along the North side of lake to the water intake building, then along the water pipe line for a short distance before crossing back (north) to "Abandoned Road" to the back of the CFS Alert HQ buildings.
19	WilliamIsA.txt	GPS track of Williams Island (21 Apr 02) perimeter. Starting on the south side near the west end and traveling clockwise around the shoreline, as the grounded icebergs would permit. This track may be useful to pull the Island out of a winter / spring radar image displaying significant ice clutter.

Appendix B: List of permanent scatterers measured in and near Alert

Way Point I.D.	Date and Time (local)	UTM – Position	Altitude	EPE ± m
64	25/07/2002 12:45	20 X 509617 9160638		
Fuel Tank #1(68)	28/07/2002 8:14	20 X 509267 9160987	83.8 m	6.8
Fuel Tank #2 (69)	28/07/2002 8:16	20 X 509270 9160958	81.1 m	6.9
Fuel Tank #3 (70)	28/07/2002 8:19	20 X 509273 9160928	83.5 m	7.0
Fuel Tank #4 (71)	28/07/2002 8:21	20 X 509275 9160900	84.0 m	7.0
Fuel Tank #5 (72)	28/07/2002 8:25	20 X 509321 9160908	86.2 m	6.9
Fuel Tank #6 (73)	28/07/2002 8:28	20 X 509318 9160941	76.3 m	5.5
Fuel Tank #7 (74)	28/07/2002 8:30	20 X 509315 9160967	79.4 m	7.0
Fuel Tank #8 (75)	28/07/2002 8:32	20 X 509311 9160998	82.8 m	7.1
76	28/07/2002 8:54	20 X 509768 9161912	49.4 m	
Crushed Stone Pile (77)	28/07/2002 9:30	20 X 509506 9161639	47.5 m	4.3
Crushed Stone Pile (78)	28/07/2002 9:32	20 X 509504 9161554	48.4 m	4.9
Pump Stn Wood Bldg (79)	28/07/2002 10:00	20 X 507895 9159014	32.3 m	7.3
Pump Stn Transformer (80)	28/07/2002 10:02	20 X 507846 9159040	31.1 m	7.3
Pump Stn Generator (81)	28/07/2002 10:03	20 X 507844 9159062	32.3 m	8.0
Pickup Structure (82)	28/07/2002 10:07	20 X 507760 9159005	29.9 m	6.7
Met Stn Sensors (83)	29/07/2002 11:19	20 X 509934 9162491	26.1 m	5.5
Met Stn Shack (84)	29/07/2002 11:22	20 X 510013 9162564	21.8 m	4.9
HydroGraphic BM (85)	29/07/2002 11:38	20 X 509959 9159787	2.0 m	4.8
Cnr-Seal Upper Dumbell (86)	30/07/2002 9:57	20 X 506967 9159589	29.7 m	5.0
Metal Bldg Upper Dumbell (87)	30/07/2002 10:11	20 X 506305 9159556	34.0 m	7.9
Cnr-Sandpiper Lower Dumbell (88)	30/07/2002 10:22	20 X 506003 9160000	26.3 m	4.0
89	30/07/2002 10:27	20 X 506004 9160001	26.3 m	
90	30/07/2002 10:27	20 X 506004 9160001	27.0 m	
91	30/07/2002 10:28	20 X 506006 9159999	27.8 m	
Post near Cnr Caribou (92)	30/07/2002 14:16	20 X 512969 9160724	13.1 m	6.0
Cnr Caribou Sickle Point (93)	30/07/2002 14:49	20 X 512895 9160716	12.4 m	6.4
Cnr Bear Toy Sickle Pt (94)	30/07/2002 15:11	20 X 513351 9160508	8.8 m	6.2
Post near Cnr Bear Toy (95)	30/07/2002 15:15	20 X 513353 9160534	13.1 m	9.6
96	30/07/2002 15:34	20 X 513369 9160515	7.1 m	
97	30/07/2002 15:34	20 X 513368 9160514	4.2 m	
Cnr Caribou Sickle Point (98)	30/07/2002 18:35	20 X 512894 9160716	14.5 m	6.8
Cnr Bear Toy Sickle Point (99)	30/07/2002 19:13	20 X 513352 9160507	19.4 m	5.8
Jan's Photo Series (100)	30/07/2002 20:28	20 X 513600 9160591	7.3 m	7.0
Jan's Photo Series Lg Ice (101)	30/07/2002 21:26	20 X 512751 9161008	6.1 m	5.0
Cnr-Sandpiper Lower Dumbell (102)	31/07/2002 17:04	20 X 506004 9160001	28.0 m	
Cnr-Seal Upper Dumbell (103)	31/07/2002 18:02	20 X 506966 9159588	24.9 m	
104	02/08/2002 20:42	20 X 502747 9156604	31.1 m	

Ice Cave (Tunnel) (105)	02/08/2002 21:13 20 X 502558 9155508 16.9 m	
Cairn NW White Pond (106)	02/08/2002 22:12 20 X 501020 9155288 196.7 m	
Love Shack Kirk Lake (107)	02/08/2002 23:10 20 X 502656 9156692 18.2 m	
Antenna East of Narrows (108)	03/08/2002 18:12 20 X 510980 9160387 41.5 m	6.6
Cnr Caribou Sickle Point (109)	03/08/2002 19:05 20 X 512896 9160715 6.6 m	4.6
Cnr Bear Toy Sickle Point (110)	03/08/2002 19:34 20 X 513350 9160504 13.8 m	4.3
Cnr-Sandpiper Lower Dumbell (111)	03/08/2002 20:46 20 X 506003 9159999 23.9 m	4.3
Cnr-Seal Upper Dumbell (112)	03/08/2002 21:16 20 X 506967 9159586 24.2 m	5.0
Bench Mark Tide Shack (113)	04/08/2002 20:36 20 X 509615 9160053 58.0 m	4.8
GPS Antenna Tide Shack (114)	04/08/2002 20:39 20 X 509618 9160060 42.9 m	
Perry Winter over Quarters (115)	06/08/2002 11:22 20 X 521962 9157046 5.4 m	
Tin Can Deposit (116)	06/08/2002 12:07 20 X 522138 9156568 7.6 m	
Barrel Hoops (117)	06/08/2002 12:24 20 X 522847 9155570 12.9 m	
Mel Christian Petersen May 1876 (118)	06/08/2002 12:48 20 X 522636 9155125 54.7 m	
Cairn Two Trees (119)	06/08/2002 13:12 20 X 521681 9154846 140.5 m	
Cairn White Cross "R" (120)	06/08/2002 13:34 20 X 521508 9155424 132.5 m	
3 (Rock) Foundations on Beach (121)	06/08/2002 14:21 20 X 522093 9156632 14.5 m	
Ross & Marvin 10April 1909 (122)	06/08/2002 14:29 20 X 521583 9156697 54.7 m	
Cairn above Jolliffe Bay	02/08/2002 18:08 20 X 506729 9161513	3.0
Lancaster Crash Site	02/08/2002 18:58 20 X 509144 9160287	
DC-4 Crash Site Edge of Runway	02/08/2002 19:21 20 X 510720 9162673	
Monument 31 July 1950 Air Crash	02/08/2002 19:35 20 X 510956 9163513	
ALERT HQ	24/07/2002 19:17 20 X 509605 9160642 75.8 m	
ALERT Corner	25/07/2002 12:41 20 X 512907 9160708	
BEARTOY Corner	26/07/2002 21:01 20 X 513354 9160506 2.8 m	
CARIBOU Corner	26/07/2002 19:52 20 X 512895 9160714 0.1 m	
DUMBELL Corner	25/07/2002 17:52 20 X 507000 9159600	
RAVINE Corner	25/07/2002 12:49 20 X 513351 9160501	
SANDPIP Corner	27/07/2002 10:07 20 X 506004 9160003 25.6 m	
SEAL Corner	27/07/2002 11:29 20 X 506967 9159588 18.2 m	
SICKLE Corner	25/07/2002 17:58 20 X 506000 9160000	
CREEK	25/07/2002 21:02 20 X 506165 9159504 21.8 m	
CRN SE JFB	02/08/2002 17:40 20 X 506729 9161513 133.0 m	
DC4 CRASH	02/08/2002 17:50 20 X 510720 9162673 -0.1 m	
ICE CAVE Tunnel	28/07/2002 18:20 20 X 502600 9155600	
LANCASTER Site	02/08/2002 17:47 20 X 509144 9160287 -0.1 m	
Monument 1950 Alert	02/08/2002 17:53 20 X 510956 9163513 -0.1 m	
Spinnaker Bldg	24/07/2002 15:25 20 X 509794 9161937 28.5 m	
Hercules 1991 crash site	1/05/2002 18:01 20 X 521267 9147610	
Oopic Island (162) – top centre	26/04/2002 23:02 20 X 499289 9160045	
Williams Island (109) – SW end	23/04/2002 01:51 20 X 504240 9162661	
Williams Island – NE end	21/05/2002 20 X 505082 9164532	

Appendix C: List of Alert ground truth photo set from Spring 2002

The ground truth photo set for Spring 2002 was extracted from a much larger photo collection taken by L. Land, DRDC-Ottawa photographer, between the 28th of March and the 3rd of May 2002. The geographic area covered is approximately 15 square kilometres centred near Canadian Forces Station (CFS) Alert. The photos have been separated into file sets based on local geographic areas of interest. At this point each file folder still has to be reviewed for content and redundancy. Also note that the same photo may be found in more than one file due to the overlapping nature of some of the geographic areas and the camera perspective.

The CFS Alert area presents a large number of geographic features that allow easy correlation of photographic and satellite images to a topographic map of the area. These include fresh water lakes and streams, salt-water bays and inlets, as well as significant hills and unique landmasses. To aid the radar images 1-metre corner reflectors were installed on the Ravine Bay shoreline side of Sickle Point. More detail on this subject can be reviewed in other sections of this document. Judging subject distance and size can be very difficult in the snow covered Arctic environments, so when reviewing photo images take care to try and find a point of reference. The two photos of Williams Island in Figure 19 and Figure 20 below illustrate how care must be exercised when reviewing photos for the size of icebergs and pressure ridges.

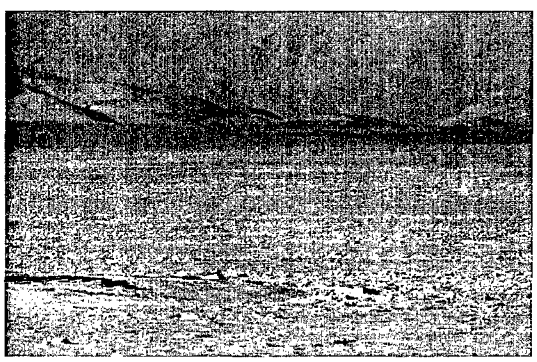

Figure 19: Williams Island, North-East [DRDC Ottawa 02-1751].

Figure 20: Williams Island, south-west, windward shoreline [DRDC Ottawa 02-3058].

Note the parallel lines of ice ridges going into the background of the left photo; the ice height in these ridges can vary from 2 to 4 metres and these are in shore fast ice. The ice grounding on the Island or the shoreline is another point of interest. Figure 19, lee side of the island, shows that the ice ridging is not too extensive, while Figure 20 shows just a small example of grounded bergs and ice ridging that can take place on the windward side of Williams Island.

Table 2: Lists the file or directory names to which the various spring photographs were assigned.

Aircraft Crash Sites	Lower Dumbell Lake
Airstrip – CFS Alert	Mount Pullen
Black Cliffs	Oopik Island
Cairns	Ravine Bay
Cape Belknap	Road (Station)
Cape Richardson	Scour
Cape Woollen	Shoreline
CFS Alert	Sickle Point
Colan Bay	Soil Surface
Dumbell Creek (lower)	Thule (Greenland)
Hilgard Bay	Upper Dumbell Lake
Ice-Camp	Weather
Ice Field	Williams Island
Jolliffe Bay	

The comparison of spring to summer photos is another area that can be very interesting from a visual and orientation perspective.

Figure 21: Lower Dumbell Creek flowing from Lower Dumbell Lake to Colan Bay. Top left corner is Colan Bay [DRDC Ottawa 02-8536].

Figure 22: This is the first 90° corner when travelling from Lower Dumbell Lake towards Colan Bay. The camera was looking east toward the lake [DRDC Ottawa 02-8696].

While the photos in Figure 21, Figure 22, Figure 23, and Figure 24 are not from the exact same perspective, they are close enough to illustrate the care that must be taken when reviewing these photo sets.

Figure 23: Same corner as illustrated in Figure 22 [DRDC Ottawa 02-3320].

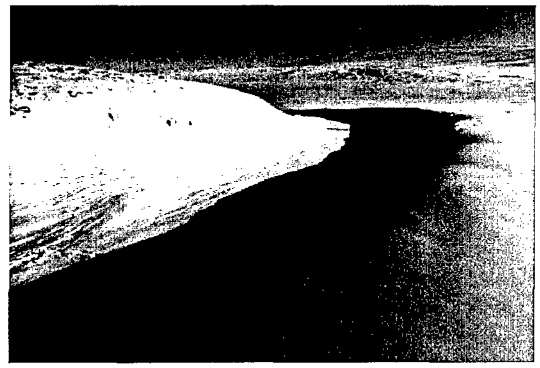

Figure 24: Same corner as illustrated in Figure 22 [DRDC Ottawa 02-3321].

While the names of the corner reflectors deployed on Sickle Point during the spring and summer changed, the two geographic locations used di dnot. The positions are compared below.

Alert corner 20 X E512905 N9160711 Caribout corner 20 X E512895 N9160714

Ravine corner 20 X E513351 N9160504 Bear Toy corner 20 X E513354 N9160506

The table that follows identifies the various photo directories with brief comments on the individual photos.

Date '02	Photo No.	File Folder	Comments
01 Apr	02-0565 - 0567	Aircraft	1950 RCAF Lancaster Crash Site, SW of Station.
24 Apr	02-3222 - 3233	Aircraft	US Air Transport C-54, South side of Airstrip.
30 Apr	111-1137R & 11-1146	Aircraft	Hercules Carsh site (1991)
04 Apr	02-0775 - 0783	Airstrip	Hercules departing from NE end of runway.
26 Apr	02-3282 - 3284	Airstrip	Airstrip surface
30 Mar	02-0311	Cape Belknap	From the air.
22 Apr	02-3038 - 3041	Cape Belknap	From Dumbell Bay looking North
06 Apr	02-1159 - 1160	Black Cliffs	Looking from Pusher Antenna array
09 Apr	02-1638 - 1639	Black Cliffs	From Ice Camp Area
10 Apr	02-1736	Black Cliffs	Taken from the saddle above Jolliffe Bay
10 Apr	02-1748; 1857;	Black Cliffs	
14 Apr	02-2279; 2434	Black Cliffs	
16 Apr	02-2580	Black Cliffs	
17 Apr	02-2806	Black Cliffs	
20 Apr	02-2807	Black Cliffs	
20 Apr	02-2927 - 2937	Black Cliffs	Pan
23 Apr	02-3066 - 3067	Black Cliffs	Taken from Williams Island
23 Apr	02-3086 - 3088	Black Cliffs	Taken from Williams Island

11 Apr	02-1865 - 1866	Cairn	CCGS Louis St. Laurent 22Aug 1971 N 82° 56' / W60° 30'
24 Apr	02-3212 - 3215	Cairn	Millennium Cairn 2000 (17 June 2000) on top of Cairn Butte.
6 Apr	02-1161; 1309;	Ice Camp	
7 Apr	02-1314	Ice Camp	Looking in from Bear Bait Camp trail.
22 Apr	02-3043	Ice Camp	
23 Apr	02-3073		
19 Apr	02-2755	Cape Richardson	
27 Apr	02-3446 - 3456	Cape Richardson	Black Cliffs to Cape Richardson
7 Apr	02-1309	Cape Woollen	Ice Camp with Cape Woollen and Black Cliffs Bay in the background.
7 Apr	02-1314	Cape Woollen	Ice Camp with Cape Jolliffe; Cape Woollen and Black Cliffs Bay in the background.
9 Apr	02-1636	Cape Woollen	Ice Camp with Cape Woollen and Black Cliffs Bay in the background.
10 Apr	02-1734	Cape Woollen	Cape Woollen and Black Cliffs shot from the saddle above Jolliffe Bay.
20 Apr	02-2935		
23 Apr	02-3074	Cape Woollen	Cape Woollen with Black Cliffs Bay in the background, shot from Williams Island.
23 Apr	02-3082 - 3086	Cape Woollen	Cape Woollen with Black Cliffs Bay in the background, shot from Williams Island
27 Apr	02-3486	Cape Woollen	Cape Woollen with Black Cliffs Bay in the background, shot from Ice Camp (high winds)
30 Mar	02-0307 - 0309	CFS Alert	Aerial photo from Hercules unon arrival. Over all shot looking across Cairn Butte, Alert Inlet, CFS Alert, Dumbell Bay, Airstrip, Jolliffe Bay, Cape Jolliffe, Cape Woollen, Black Cliffs Bay and Black Cliffs, and Williams Island. 02-0309 includes Ravine Bay, Sickle Point and Cape Belknap.
26 Apr	02-3330 - 3358	Colan Bay	02-3330 - 3333 Colan Bay looking out from Dumbell Creek Delta. 02-3334 - 3336 Looking across at where the bat narrows. 02-3342 & 3349 The saddle that runs across Smith Peninsula. 02-3350 – 3358 Ice ridge at mouth of Colan Bay (Cape Woollen).
30 Apr	02-3695 - 3737	Colan Bay	02-3695 - 3699 Shooting from Cape Jolliffe across Colan Bay to the saddle that runs across Smith Peninsula, then panning North to Black Cliffs and beyond.

30 Apr	02-3701 - 3721	Colan Bay	This series of photos shows the wind effects of soil erosion from the Smith Peninsula saddle on Colan Bay north of the narrows
30 Apr	02-3722 - 3723	Colan Bay	Smith Peninsula rock face (wall) west side of Colan Bay north of the narrows.
30 Apr	02-3727 - 3730	Colan Bay	Effects of the soil scour on the Bay ice surface looking back toward Cape Jolliffe.
30 Apr	02-3731 - 3735	Colan Bay	Soil conditions in the Smith Peninsula saddle.
26 Apr	02-3319 - 3329	Lower Dumbell Creek	Creek bed between Lower Dumbell Lake and Colan Bay.
26 Apr	02-3383 - 3387	Hilgard Bay	Shots of the Bay taken from Oopik Island.
30 Mar	02-0310 - 0312	Ice Field	General shots from Herc before landing at CFS Alert.
2 Apr	02-0588 - 0590	Ice Field	Grounded Iceberg
3 Apr	02-0700; 1159	Ice Field	General shots near the Ice Camp
6 Apr	02-1504; 1763		
10 Apr	02-1764; 1852		
14 Apr	02-2275 - 2278	Ice Field	Near Black Cliffs
14 Apr	02-2345 – 2348 & 02-2474	Ice Field	General shots
17 Apr	02-2543 - 2545	Ice Field	General shots
26 Apr	02-3359 - 3400	Ice Field	Iceberg near Cape Woollen
30 Apr	02-3739 - 3741	Ice Field	Ice rafting near Cape Woollen.
1 Apr	02-0514 - 0515	Jolliffe Bay	Shoreline at Jolliffe Bay
1 Apr	02-0579; 0581	Jolliffe Bay	Looking from the Cape Jolliffe saddle into Jolliffe Bay
10 Apr	02-1729	Jolliffe Bay	Looking from the shoreline NW with Ice Camp centred.
10Apr	02-1738	Jolliffe Bay	Looking from the shoreline NW with Ice Camp on right.
16 Apr	02-2430 - 2433	Jolliffe Bay	Looking NW across the Jolliffe Bay with Williams Island and Black Cliffs on the left.
17 Apr	02-2470 - 2472	Jolliffe Bay	From the hill behind the Ice Camp looking back into Jolliffe Bay.
23 Apr	02-3081	Jolliffe Bay	Looking from the shoreline NW with Ice Camp centred.
18 Apr	02-2655 - 2659	Lower Dumbell Lake	Looking from the NE end of the lake toward the SW.
26 Apr	02-3310 - 3311	Lower Dumbell Lake	Looking across the lake toward the Dumbell Creek exit.
26 Apr	02-3312	Lower Dumbell Lake	Looking across the lake toward north shore
26 Apr	02-3313 - 3316	Lower Dumbell Lake	Pan from Upper Dumbell Creek clockwise to the north shore

26 Apr	02-3317-3318	Lower Dumbell Lake	Shot across Upper Dumbell Creek.
28 Apr	02-3560 - 3562	Lower Dumbell Lake	Shot across Lower Dumbell Lake.
6 Apr	02-1165	Mount Pullen	Looking south
28 Apr	02-3634	Mount Pullen	Looking south
26 Apr	02-3388 - 3398	Oopik Island	Shots around Black Cliffs Bay from Oopik Island.
30 Mar	02-0309	Ravine Bay	Shot from Herc prior to arrival at CFS Alert.
11 Apr	02-1924	Ravine Bay	Looking SW from Sickle Point across Ravine Bay toward to south end of Cairn Butte.
11 Apr	02-1925 - 1926	Ravine Bay	Looking west into Ravine Bay toward Cairn Butte.
01 Apr 06 Apr	02-0476 02-1015 - 1016	Road	Road near base water intake plant down to Upper Dumbell lake looking west.
06 Apr	02-0965	Road	Road from near the tank farm looking NE toward the gravel piles and on to the airstrip.
09 Apr	02-1667	Road	Road near the water pumping station, it runs west down to and along the shoreline of Upper Dumbell Lake. The camera is looking east.
30 Apr	02-3701 - 3718	Scour	This series shows the effects of wind soil scour on Colan Bay at the saddle that runs across Smith Peninsula.
09 Apr	02-1546 - 1552	Shoreline	Jolliffe shoreline, with the Bear Bait camp in the background. 1552 close up of the same shoreline.
11 Apr	02-1891 - 1900	Shoreline	Sickle Point shoreline Lincoln Sea side
11 Apr	02-1901 - 1902	Shoreline	Sickle Point shoreline Ravine Bay side looking out toward Lincoln Sea.
11 Apr	02-1872 - 1900	Sickle Point	Sickle Point shoreline Lincoln Sea side photographed from near the Louis St Laurent Cairn.
11 Apr	02-1902	Sickle Point	Sickle Point shoreline Ravine Bay side near the Lincoln Sea end.
11 Apr	02-1903 - 1904	Sickle Point	Shooting from Sickle Point across Ravine Bay to Mushroom Point.
11 Apr	02-1905 - 1910	Sickle Point Ravine Corner	Shooting from Ravine Bay shoreline north across Sickle Point, also illustrate a 1-metre radar corner deployment. Same corner shot from the opposite side toward Mushroom Point
11 Apr	02-1911 - 1923	Sickle Point Dumbell Corner	Shooting from Ravine Bay shoreline west toward the next corner (~250 m west).

11 Apr	02-1927 - 1936	Sickle Point Sickle Corner	Shooting from Ravine Bay shoreline east toward the Lincoln Sea inlet.
24 Apr	02-3152 - 3165	Sickle Point Alert Corner	Ravine Bay shoreline illustrating snow filled Alert corner, with surge line. Also tide cracks parallel to shoreline.
24 Apr	02-3166 - 3176	Sickle Point Dumbell Corner	A series of photos shooting around the Dumbell corner.
24 Apr	02-3177 - 3195	Sickle Point Ravine Corner	A series of photos shooting around the Ravine corner. Also shows the fact that a Polar Bear disturbed the corner set up.
24 Apr	02-3196 - 3211	Sickle Point Sickle Corner	A series of photos shooting around the Sickle corner. Also shows the fact that a Polar Bear disturbed the corner set-up. This corner was deployed at the Lincoln Sea end of Sickle Point.
23 Apr	02-3076 - 3104	Soil Surface	A series of photos shot on Williams Island showing the different soil types and conditions.
28 Mar	02-0293	Thule	Mount Dundas
3 May	02-3862; 3869; 3873; 3881	Thule	Mount Dundas
3 May	02-3862 - 3877	Thule	Harbour area
3 May	02-3881	Thule	Mound Dundas as above on 28 March.
1 Apr	02-0477 - 0483	Upper Dumbell	Looking south across the lake near the station water intake plant.
1 Apr	02-0504 - 0506	Upper Dumbell	Looking east from the west end of the lake toward the station water intake plant.
6 Apr	02-1172 - 1174 Good Over all shot	Upper Dumbell	Looking south across the lake with the station water intake plant on the left and the GAW lab centred on the plain above the lake and Mount Pullen in the background. 02-1173 is a close-up of the previous shot. The barrel to the right and behind the intake shack is the first deployment location for the GPS interference test. Note antennae near the GAW Lab. The photo series is a pan from south to east.
9 Apr	02-1668	Upper Dumbell	Looking south across the lake from the road with the station water intake plant on the right.
9 Apr	02-1669	Upper Dumbell	Looking south-west across the lake from the road above the station water intake plant on the left.
9 Apr	02-1670 - 1671	Upper Dumbell	Looking south-west across the lake from the road with the station water intake plant. 02-1668 to 1671 is a pan from south to west.

16 Apr	02-2385 - 2386	Upper Dumbell	Looking North from the plain above the south end of the lake.
16 Apr	02-2426 - 2429	Upper Dumbell	Looking to the South end of the lake. The winds are up. 02-2429 pans south to west.
18 Apr	02-2654	Upper Dumbell	Looking South across the lake from the saddle up to Jolliffe Bay with Mount Dean and Pullen in the background.
28 Apr	02-3561	Upper Dumbell	Looking South across the lake from the saddle up to Jolliffe Bay with Mount Dean and Pullen in the background.
28 Apr	02-3627 - 3631	Weather	Interesting cloud pattern looking south from CFS Alert toward Mount Dean.
2 Apr	02-0601	Williams Island	Initial build of Ice Camp in fore ground.
6 Apr	02-1159	Williams Island	From Pusher Antenna Array looking west to Black Cliffs and Knot Bay on the right side of photo.
9 Apr	02-1544 - 1545	Williams Island	From the Jolliffe Bay saddle looking at the SW end of the Island.
10 Apr	02-1741	Williams Island	From the Jolliffe Bay saddle looking north across the east end of the Island.
10 Apr	02-1747 - 1748 02-1752 02-1756 – 1758 02-1739	Williams Island	From the Jolliffe Bay saddle looking north west across the south-west end of the Island with Black Cliffs in the background.
10 Apr	02-1749 02-1753; 1740	Williams Island	From the Jolliffe Bay saddle looking north across the centre of the Island.
10 Apr	02-1750 – 1751 02-1754	Williams Island	From the Jolliffe Bay saddle looking north across the north-east end of the Island.
10 Apr	02-1759	Williams Island	From the Jolliffe Bay saddle looking at the high point of the Island. Close-up.
10 Apr	02-1757 - 1762	Williams Island	From the Jolliffe Bay saddle a close-up pan of the Island from west to east.
10 Apr	02-1765 - 1766	Williams Island	From the Jolliffe Bay saddle a close-up with bear bait camp in fore ground.
22 Apr	02-3035 - 3036	Williams Island	Williams Island south side shoreline looking south-west.
22 Apr	02-3037	Williams Island	Williams Island south side shoreline looking north-east.
22 Apr	02-3040	Williams Island	From Williams Island looking south to the shoreline of Cape Belknap.
22 Apr	02-3042	Williams Island	From Williams Island looking south-west to the shoreline of Cape Woollen.
22 Apr	02-3045 - 3046	Williams Island	From the south-west end of Williams Island shoreline looking North-east straight into the Island.
22 Apr	02-3047	Williams	From the south-west end of Williams Island

	02-3049 02-3051	Island	shoreline looking north-east up the North shoreline of the Island.
22 Apr	02-3048	Williams Island	From the south-west end of Williams Island shoreline looking North-east up the South shoreline of the Island toward Cape Belknap.
22 Apr	02-3050 02-3052	Williams Island	Looking north from the south-west end of Williams Island. The shoreline is lined with grounded icebergs.
22 Apr	02-3053 - 02-3054 02-3087 - 02-3092	Williams Island	Looking south-west from the south-west end of Williams Island towards the Black Cliffs Bay shoreline.
22 Apr	02-3056	Williams Island	Looking south into Jolliffe Bay with Mount Pullen in the deep background.
22 Apr	02-3058	Williams Island	Looking north at the grounded icebergs on the North shoreline of Williams Island.
22 Apr	02-3059	Williams Island	Looking west at the grounded icebergs on the North shoreline of Williams Island.
22 Apr	02-3060 - 3063	Williams Island	Looking north at the grounded icebergs on the North shoreline of Williams Island.
23 Apr	02-3083 - 3084	Williams Island	Looking east from Williams Island with the Ice Camp and Jolliffe Bay on the right and Cape Belknap in the distance.
23 Apr	02-3087 - 3105	Williams Island	Looking south-west from the south-west end of the Island with a pan going from SW to NE
23Apr	02-3106 - 3108	Williams Island	Looking east from NE end of the Island and panning east and north.

Appendix D: List of Alert ground truth photo set for summer 2002

What follows consists of a list of photographs with a brief description taken by Janice Lang and Lloyd Gallop from July 23rd through to August 8th. The photographs themselves have been archived on disk at DRDC. Additional hand-written and typed notes that further detail some of the individual photos are also available upon request.

Date '02	Photo No.	Local Area	Comments
23 July	02-7199 - 7209	Hercules Flight Deck	
	02-7210 - 7235	From Hercules	In route from Trenton to Thule
24 July	02-7236 - 7240	Thule	
	02-7279 - 7342	Thule to Alert	Aboard Hercules
	02-7343 - 7369	Polar Dip I	
	02-7370 – 7382 02-7241 – 7278 02-7396 - 7468	Dean Hill Trip	By BV-206
	02-7474 - 7537	Hilgard Bay Trip	Track Truck - PM
25 July	02-7539	Dumbell Bay	
	02-7539 - 7575	Corners to Sickle Pt.	
	02-7576 - 7592	Ice at the end of runway	
26 July	02-7733 - 7790	Corner Deployment	At Sickle Point
	02-7791 - 7819	Conditions	At Sickle Point
27 July	02-7820 -	Dumbell Bay	
	02-7821 - 7823	CFS Alert Bldg	
	02-7824 - 7862	Lower Dumbell	Corner Deployment
	02-7863 - 7890	Lower Dumbell	Shoreline and Panoramas
	02-7891 - 7909	Dumbell Creek	Between Upper and Lower Dumbell
	02-7912 - 7921	Upper Dumbell	Corner Deployment
	02-7922 - 7963	Upper Dumbell	Shoreline and Panoramas
28 July	02-7993 - 7999	Alert Departure	
	02-8000 -8070	Polar Dip II	Few pictures of ice conditions at end of runway.
29 July	02-8081 - 8123	Upper Dumbell	Shoot of water intake station and pipeline.
	02-8124 - 8149	Colan Bay	From BV track
	02-8150 - 8206	Kirk Lake Valley	Wide variation in soil and topography conditions
	02-8207 - 8287	Hills above Hilgard Bay	
30 July	02-8289 - 8290	Alert Inlet	Shoreline

	02-8291 - 8442	Sickle Point	Shoreline and Tide difference
The following set of Aerial photos of CFS Alert area were taken by J. Lang with flight suppor tprovided by a CC-138 Twin Otter from 440 Squadron out of Yellowknife, NWT. The Twin departs the Alert runway heading NE, turns north, then west climbing to 7000 feet by the time it reaches Cape Richardson. It then turns south covering the coastline of Black Cliffs Bay and Hilgard Bay. Next the place turns east and follows a line between Winchester Hills and the Station covering Kirk Lake, Colan Bay, Upper and Lower Dumbell lakes, Alert Inlet, Dumell Bay, Mushroom and Sickle Point, and finally Cape Belknap. At this point the plane descens to 4000 feet and flies a tighter circuit covering the north side of the Station, Upper and Lower Dumbell Lakes, Colan Bay, then back around on the south side of the Lakes. The sun was in the south-west shinning to the north-east.			
31 July 02	02-8443	Alert Airstrip	Twin Otter Flight (Sqdn-440)
	02-8458	Victoria Lake	Knots Bay into Black Cliffs Bay
	02-8460/61	Knots Bay/Black Cliffs	
	02-8462/63	Colan Bay	
	02-8464/65	Black Cliffs/Hilgard Bay	Frozen Egerton Lake
	02-8466	Black Cliffs Bay	Looking east toward CFS Alert
	02-8467	Egerton Lake/ Hilgard Bay	Kirk Lake, Winchester Hills
	02-8468	Black Cliffs Bay/ Egerton Lake/ Hilgard Bay/Colan Bay	Moss Pond/ Kirk Lake/White Pond/U&L Dumbell Lake/ Winchester Hills
	02-8469	CFS Alert overview	Shows shore ice that is protected from wind by Cape Belknap.
	02-8471	Hilgard Bay	
	02-8472		Stream into Hilgard Bay from west and south
	02-8474	Hilgard Lake	
	02-8479	Over all View	Looking west from Hilgard
	02-8480	Bowery Inlet	
	02-8481	Egerton Lake	70% Frozen – Oopik Island
	02-8483	Moss Pond	
	02-8484	Black Cliffs Bay	Looking north
	02-8486	Black Cliffs Bay east	Note shale shoreline vs clay on the hills.
	02-8487	Moss Pond	
	02-8488	Moss Pond, Colan Bay, Kirk Lake,	Edge of Lower Dumbell Lake
	02-8490	Colan Bay, Kirk Lake	
	02-8491	Colan Bay, Jolliffe Bay	and Williams Island
	02-8492/93	Entrance to Colan Bay	

	02-8494	U & L Dumbell Lakes	
	02-8495	Overall View	Colan Bay, Williams Island, U & L Dumbell Lakes, Dumbell Bay, Alert Inlet, Stn, and portion of Ravine Bay, Open water to Lincoln Sea
	02-8496/97	Colan Bay	Looking north through Colan Bay
	02-8498	U & L Dumbell Lakes	Dumbell Bay, Alert Inlet
	02-8499	U & L Dumbell Lakes	
	02-8500/01	CFS Alert	Alert Inlet looking into Dumbell Bay
	02-8502/03	As above with	Ravine Bay and Sickle Point
	02-8504	Sickle Point	
	02-8505	Cairn Butte onto	Sickle Point
	02-8506/07	Sickle Point	
	02-8508	CFS Alert and	Alert Inlet
	02-8509	Alert Inlet	
	02-8510	Dumbell Bay	End of runway, Met stn, Spinnaker
	02-8511	Runway, Belknap Pt	
	02-8512/13	Sickle Point	
	02-8514		
	02-8515/16/17/ 18*/19/20	Overall View	Looking North and West
	02-8522	Runway	
	02-8523	Sickle Point	Ravine Bay, Cairn Butte
	02-8524	Overall view	Centered on CFS Alert
	02-8525	Sickle Point	Looking south
	02-8526/27/28	Sickle Point	And Mushroom Point, Dean & Pullen Mountains, Self Pond
	02-8529	Winchester Hills	& CFS Alert
	02-8530	CFS Alert	With Hercules on Spot #2
	02-8531	Upper Dumbell Lake	And Tern Island
	02-8532	Lower Dumbell Lake	& Creek
	02-8533	Lower Dumbell Lake	& Creek into Colan Bay
	02-8534	Colan Bay Narrows	Note Salt effervesce
	02-8535/36/37/38	Kirk Creek Delta	Note Salt
	02-8539	Dumbell Creek into	Colan Bay
	02-8540	Lower Dumbell Lake	Near Creek exit.

	02-8541	May Creek Delta	At Lower Dumbell Lake
	02-8544	Upper Dumbell Creek	
	02-8545	Tern Island in Upper Dumbell Lake	
	02-8546	Upper Dumbell Lake	Water intake for station
	02-8547	Stn looking from	Upper Dumbell
	02-8548/49	Stn looking from NE	
	02-8550/51	U & L Dumbell Lake	
	02-8552	Upper Dumbell Lake	
	02-8553	Lower Dumbell Lake	And Creek into Colan Bay
	02-8554/55/56	Stn, Dumbell Bay	And Alert Inlet
	02-8557/58	Ravine Bay	And looking out to Sea
	02-8559	Alert Inlet & Stn	
	02-8560/61/62	Alert Inlet looking	NW to Cape Richardson
	02-8563/64/65	Ravine Bay &	Sickle Point
	02-8566	Sickle Point	
	02-8567/68	Runway	
	02-8569/70/71	Ravine Bay,	Alert Inlet
	02-8572/73*	CFS Alert	
	02-8575/76/77/78	Runway	
	02-8580	Runway Apron with	Hercules 338
	02-8581	CFS Alert	
	02-8582 to 83	Cape Belknap	
	02-8585	Aeriel view of Bergs	
	02-8587/88/94/ 95/96/97	Twin Otter-440 Sqdn	
	02-8589/90/ 8600/16	Fuel Tanks at Runway	
	02-8592	Met Shack	
	02-8593	Hercules 338 under	service
	02-8599/8612/13	Spinnaker	
	02-8602	Runway Texture	
	02-8603	Runway apron	
	02-8617/18	Stn fuel line	
	02-8619 to 8628	Tank Farm	

	02-8629/30	Pipe storage	East of tank farm
	02-8631/32	Fuel cache	
	02-8634	Stn Fuelling area	
	02-8635 to 41	Stn buildings	
	02-8642	Water line near stn	
	02-8644	HAPS ramp	
	02-8650 - 8651	Dumbell Bay	
	02-8686 - 8660	Seal Corner	Upper Dumbell
	02-8661 - 8716	Dumbell Creek	And Surrounds
	02-8717 - 8749	Colan Bay	Shoreline
01 Aug	02-8750 - 8760	Tide Gauge	Installation
	02-8761 – 8774 02-8780 - 8796	Dr Guy Morrison and Clair	Working with Artic Birds
	02-8797 - 8801	GAW Lab	Vivek Voora
	02-8802 - 8803	Dumbell Bay	
	02-8864 02-8894 – 8897	Lancaster Crash Site	
	02-8867	Dumbell Bay	
	02-8868	Williams Island	
	02-8872	Dumbell Bay	
	02-8873 – 8877	Upper Dumbell Lake	From GPS horn site
	02- 8878 – 8879	Corner Seal	Upper Dumbell
	02-8880 – 8891	Black Cliffs Bay	From above Jolliff Bay
	02-8892 – 8893	Corner Sand Piper	Lower Dumbell
	02-8898 – 8900	DC-4 Crash Site	Near Runway
	02-8911 - 8948	Kirk Lake and Creek	Includes Ice cave and shots from the South Hills – Cotton Grass
	02-8949 – 8950	Colan Bay	
	02-8952 – 8953	Dumbell Bay	
	02-8954	Millennium Cairn	
	02-8955 - 8969	Sickle Point	Includes corners Caribou and Bear Toy
	02-8962 - 8963	Corner Caribou	
	02-8965 - 8967	Corner Bear Toy	
	02-8970 - 8975 02-9003 - 9005	Corner Sandpiper	
	02-8976 - 8977	Corner Seal	
	02-8978 - 8979	Dumbell Bay	
	02-8980 – 8986	Sickle Point	Tide measurements
	02-8989	CFS Alert	From narrows of Cairn Butte
	02-8991 - 8992	Tide Guage	Installation
5 Aug	02-8996 – 8998	Wolf	
	02-8999 - 9001	Sickle Point	Corner Pickup
	02-9002	Alert Inlet	Looking east
	02-9007 - 9049	Trip to Floeberg	

		Beach	
	02-9050 – 9051	Dumbell Bay	
	02-9052 – 9057 02-9082 – 9086	Arctic Hare	
	02-9058 – 9062	Sickle Point	
	02-9063 – 9068	HMS Alert 1876	
	02-9070 – 9078	Sickle Pt Icebergs	North side
	02-9079 – 9081	Alert Inlet	
	02-9087 – 9089	Turnstone	
	02-9090 – 9091 02-9101 – 9103	Spinnaker Gear	
	02-9092 – 9096	Dumbell Bay	
	02-9097	Island (unnamed)	In Upper Dumbell Lake
	02-9098 – 9099	Dumbell Bay	
	02-9106	Dumbell Bay	
24 July 25 July 27 July 31 July 01 Aug 01 Aug 02 Aug 03 Aug 04 Aug 06 Aug 07 Aug 08 Aug 09 Aug	02-7314-7316 02-7538 02-7820 – 02-8650 – 02-8802 – 8803 02-8867 02-8872 02-8952 – 8953 02-8978 - 8979 02-9050 - 9051 02-9092 - 9096 02-9098 – 9099 02-9106	Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay Dumbell Bay	
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This technical memo is part of a study to develop and test tools and techniques for improved accuracy, reliability and automation of shoreline delineation and feature extraction, with particular emphasis on the arctic environment. This memo details the RADARSAT imagery and extensive ground truth collected during the spring and summer of 2002 in CFS Alert, Nunavut. The ground truth includes deployment of four radar corner reflectors, measurement of several shorelines and a large variety of other tracks, measurement of a large variety of permanent scatterers and targets of opportunity, extensive photographic record, comparison of the measured and modeled tide at CFS Alert, and plots of the weather during the time period concerned.

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Alert, CFB Alert, SAR, Interferometry, shoreline delineation

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